GULL ROCK AND PUNGO RIVER GAME LANDS AQUATIC INVENTORY

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GULL ROCK AND PUNGO RIVER GAME LANDS
AQUATIC INVENTORY

Introduction

The Tar-Pamlico River Basin, completely contained in the state of North Carolina, originates in Person, Granville, Vance, and Warren counties and drains southeast into the Pamlico Sound. This watershed's 2,414 miles of streams drain portions of 15 North Carolina counties and encompasses 5,571 square miles of land. The Tar-Pamlico River Basin, the state's fourth largest river basin, begins in the Piedmont with clearwater streams, and east of the fall zone the waters become predominantly black and can be highly acidic. Lake Mattamuskeet, the largest natural lake in the state, and several other natural lakes are contained in this river basin. Two state-owned game lands, Gull Rock Game Land and Pungo River Game Land, lie within the lower Tar-Pamlico River Basin.

Gull Rock Game Land is located in the southern portion of Hyde County, south of Mattamuskeet National Wildlife Refuge (50,000 acres), and is bordered on the west by Swanquarter National Wildlife Refuge (16,411 acres) and on the south by the Pamlico Sound. The county capital, Swan Quarter, sits several miles west of the game land. The game land, which currently encompasses 19,436 acres, was purchased as a series of parcels. The original parcel (most of the acreage that exists today) was purchased by the North Carolina Wildlife Resources Commission (NCWRC) in 1945. Subsequently, additional adjacent parcels were obtained from private landowners, timber companies, and the North Carolina Nature Conservancy. In 1987, the NCWRC worked with the Natural Heritage Program to dedicate a portion of the game land (~9,000 acres) as a permanently protected "North Carolina Nature Preserve."

The major waterways associated with Gull Rock Game Land are Outfall Canal, which connects Lake Mattamuskeet to the Pamlico Sound, Loop Road Waterfowl Impoundment, wetlands and potholes throughout the game land, and the Pamlico Sound itself. Outfall Canal and many other canals and ditches were constructed in 1914 in an attempt to drain Lake Mattamuskeet (40,000 acres) and much of the surrounding wetlands so that the area could be developed and used for agriculture. A pump house, that is today Mattamuskeet Lodge, was built to enhance the drainage process using steam engines. After the lake was drained on 3 occasions, the operation was finally abandoned and the lake refilled in 1932. However, much of the surrounding areas remained impacted by ditches and canals. Loop Road Waterfowl Impoundment (~300 acres) was constructed from a flooded maple/gum forest during the late 1960s and early 1970s and was cleared of standing debris in the early 1980s and again in the early 1990s. It is the only impoundment of 3 that still exists. There are at least 4 types of vegetation communities present in the game land, and these are considered good examples of rare communities. They are (1) *bottomland hardwood*- consisting of primarily sweetgum and red maple, but also swamp tupelo, water elm, willow oak, American holly, persimmon, cypress, and loblolly pine, (2) *pond pine*- consisting of pond pine, bays, myrtles, and scattered cypress, (3) *low pocosin*- consisting of scattered pond pine, bays, and myrtles, and (4) *high marsh*- consisting of marsh grass and juncus. The remaining understory is mostly swamp privet. The soils are highly acidic, poorly drained with a high organic content (including some peat), and a large portion remains wet year-round. Most of the game land remains undeveloped, with only 1 main unpaved road that runs alongside

Outfall Canal and leads to a public boat ramp at Pamlico Sound, and several smaller gated roads. Additionally, there are 2 camp sites. Rare species known to occur in the game land include Southern twayblade (a peripheral plant), and American alligator. Rare communities include brackish marsh, nonriverine wet hardwood, low pocosin, high pocosin, and pond pine woodland.

The main uses of Gull Rock Game Land are hunting, fishing, and as a refuge for wintering waterfowl. It is also used for bird and other nature watching, education, and research. Much of the game land is not actively managed, except for boundary posting and road/trail and campground maintenance, due to wetland regulations. Fire management (prescribed burns and roll-chopping) is employed on approximately 850 acres to maintain rare communities and as a response to natural disasters, but these practices are minimized due to difficult accessibility. Limited vegetative management (removing exotic species and planting natives) occurs annually on about 45 acres. Additionally, approximately 8,000 acres are managed for timber and some timber and mineral rights have been sold over the years to various companies. Public hunting on the game land is permitted for fox, dove, quail, rabbit, squirrel, raccoon, deer, and waterfowl, and sportsmen actively pursue warmwater fishes. Because it is a bear sanctuary, bear hunting is forbidden. This area is known to have one of the largest remaining populations of black bear. The waterfowl impoundment is maintained as habitat for the large number of migrating waterfowl (e.g., swans, geese, ducks) that use the area and surrounding areas (especially Lake Mattamuskeet and other nearby lakes) as wintering grounds and for resident waterfowl.

Pungo River Game Land consists of 2 main parcels with a total area of 614 acres in Hyde County, one of which is located along the southern shore of Pungo River approximately 2 miles north of Sladesville and 1 mile west of Scranton, and the other is located along the Beaufort County border approximately 2 miles west of the intersection of NC 45 and US 264. The former and larger tract was acquired by The Nature Conservancy in 1983, and management of this tract was transferred to the NCWRC in 1993. The latter and smaller tract was acquired by the NCWRC in 1990 from the Department of Administration, and 3 islands were added to this tract in 1997. The predominant habitat type in the game land is open saltmarsh with abundant black needlerush, and scattered canals and potholes. The major waterways associated with the game land are the Pungo River and its tributaries, all of which are at least partly saline. No active land management occurs on the game land, except for boundary posting, due to wetland regulations. The primary purpose of this game land is for public hunting and fishing, and access is by boat only. Hunting is permitted for fox, quail, rabbit, raccoon, deer, and waterfowl, and sportsmen actively pursue warmwater fishes. The game land is considered a bear sanctuary and hunting is not permitted for this species.

Land use in the areas surrounding both game lands primarily consists of agriculture or undisturbed natural areas. A visual survey of the area reveals numerous cotton, peanut, and other row crop fields. The area in and around the game lands was heavily logged in the 1800s and early 1900s, but the natural areas have remained mostly untouched since then aside from several blocks of timber that were clearcut. Overall, the landscape in Hyde County is relatively undeveloped, and the county has only several small towns with a total population of around 6,000. There are many culturally significant buildings, old homes, and churches in the county. The areas surrounding the game land, largely consisting of wildlife refuges, provide habitat for rare species such as bald eagle, red wolf, American alligator, and an occasional peregrine falcon.

Additionally, many mammals (e.g., deer, bobcats, otters, black bears, bats, opossums, shrews, raccoons, weasels, foxes, rabbits, squirrels, many other rodents), birds (e.g., migratory songbirds, waterfowl, shorebirds), amphibians (e.g., frogs, toads, salamanders), and reptiles (e.g. turtles, lizards, at least 31 species of snakes) can be found.

The objective of this project was to survey Gull Rock Game Land, Pungo River Game Land, and surrounding areas for aquatic species, including mussels, sphaeriid clams, snails, crayfishes, and fishes. Our goals were to determine species presence, distribution, relative abundance, and relative health. The inventory included waterways in and associated with both game lands within Hyde County, North Carolina. Figure 1 and Tables 1a and 1b detail the localities of all the sites surveyed (for both game lands). The following sections provide results of the aquatic inventory for each of the taxa mentioned above. For purposes of this report, *Corbicula fluminea* (Asian clam) was grouped with the sphaeriid clams even though the 2 taxa belong to different families. It also should be noted that any plus or minus symbols listed after road numbers in the following tables represent whether we surveyed downstream or upstream, respectively.

Acknowledgements

We would like to thank the following people, without whose assistance this project would not have been possible: John M. Alderman (NCWRC) for reviewing and editing the report; Dale Davis and others at the Edenton Depot (NCWRC) for providing information and access points regarding both game lands; staff at the Mattamuskeet National Wildlife Refuge for housing and information; Dr. John E. Cooper, Dr. Arthur E. Bogan, and Dr. Wayne C. Starnes, Gabriela M. Hogue, Dr. Morgan E. Raley, and Lynn Fullbright from the NC State Museum of Natural Sciences for providing assistance with identifications of crayfishes, mollusks, and fishes, respectively; Dr. Gerald L. Mackie from the University of Guelph, Ontario, Canada, for providing assistance with sphaeriid identifications. We also would like to thank the landowners and residents of Hyde County, North Carolina, who allowed us to work on their property and showed an interest in their local natural history.

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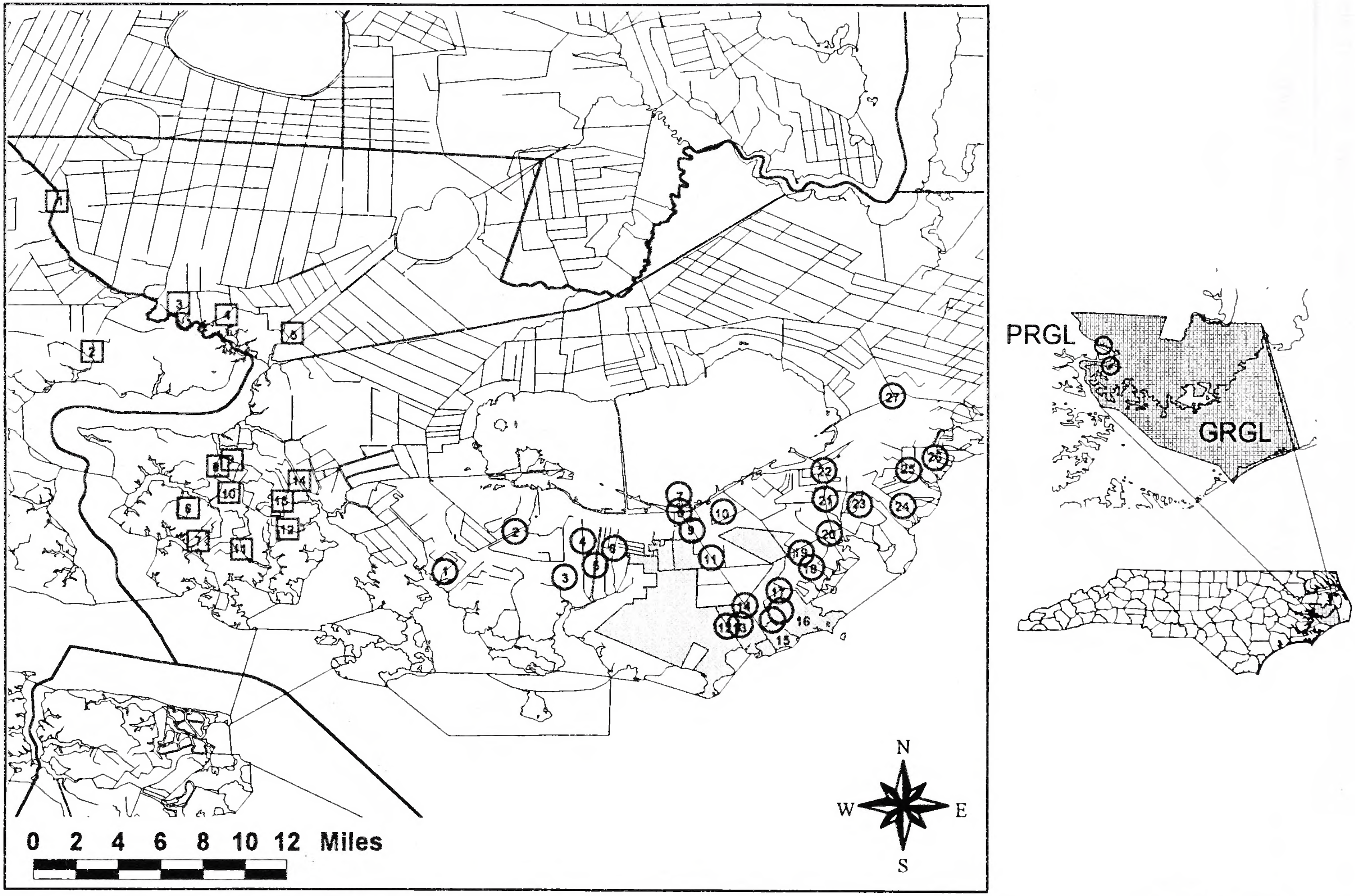

Figure 1. Maps of sites surveyed during the aquatic inventories of Gull Rock Game Land (GRGL) and Pungo River Game Land (PRGL) in Hyde County, North Carolina, 2000. Circles represent GRGL and squares represent PRGL. The location of the game lands within the county, and the location of the county within the state of North Carolina, are shown to the right.

Table 1a. Map numbers, the corresponding sites surveyed, and survey effort (person-hours/electroshock seconds) for Gull Rock Game Land (indicated by the circles on Figure 1).

Map #	Site number	Survey Effort
1	000711.1btw	1.0
2	000712.2btw	0.25
3	000711.2btw	0.5
4	000712.1btw	1.0
5	000711.3btw	0.25
6	000711.4btw	0.5/373
7	000606.6btw	0.6
8	000607.9btw	0.75
9	000607.3btw	0.5
10	000608.6btw	0.75/216
11	000607.2btw	0.1
12	000606.5btw	0.75/172
13	000606.4btw	0.1
14	000607.1btw	0.6
15	000606.1btw	1.5
16	000606.2btw	1.0
17	000606.3btw	0.1
18	000607.5btw	0.45
19	000607.6btw	1.0/308
20	000607.7btw	0.75
21	000607.8btw	0.2
22	000607.4btw	1.0
23	000608.1btw	0.25
24	000608.2btw	1.25
25	000608.3btw	0.5
26	000608.4btw	0.25
27	000608.5btw	1.0

Table 1b. Map numbers, the corresponding sites surveyed, and survey effort (person-hours/ electroshock seconds) for Pungo River Game Land (indicated by the squares on Figure 1).

Map #	Site number	Survey Effort
1	000713.5btw	0.25
2	000713.6btw	0.5
3	000713.4btw	0.3
4	000713.3btw	0.75
5	000713.2btw	0.75/243
6	000712.6btw	0.5
7	000712.10btw	0.5
8	000712.4btw	0.5
9	000712.3btw	1.0
10	000712.5btw	0.25
11	000712.7btw	0.5
12	000712.8btw	0.75
13	000712.9btw	0.5
14	000713.1btw	0.5

FRESHWATER MUSSELS AND SPHAERIID CLAMS

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Introduction

The freshwater mussel fauna (Bivalvia: Unionoidea), also referred to as unionids or pearly mussels, is an intriguing, diverse, and important group of mollusks. Unionids are often prominent in macrobenthic aquatic communities where, for the most part, they are sedentary filter-feeders. Because unionids consume a major portion of the suspended particulate matter, they provide a number of important roles in aquatic ecosystems, two of which include serving as biological filters and water quality indicators. Mussels also serve as an important dietary component to a number of animals, and economically, their shells provide the nuclei used in the profitable cultured pearl industry (Theil and Fritz 1993). While not as much information has been ascertained for the sphaeriid clams (Bivalvia: Sphaeriidae), also called pea, pill, nut, or fingernail clams, they too serve an important role in aquatic ecosystems as filter-feeders. As part of the inventory of aquatic animals associated with the state-owned Gull Rock Game Land and Pungo River Game Land, we conducted field surveys of freshwater mussels and sphaeriid clams found in waterways occurring in and around the game lands to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

The life cycle of freshwater mussels is an intricate process that is fairly unique when compared to that of other organisms. Spawning begins with the release of sperm from the excurrent aperture of mature males. As the sperm passively drift with the currents, they enter females through their incurrent aperture. Within sexually mature females, fertilization takes place in the suprabranchial cavity, and the resulting embryos are retained in the marsupial gills until they develop into parasitic larvae called glochidia. Glochidia are obligate parasites and must attach to suitable host fishes. Ortmann (1911) described 2 general reproductive modes for unionids based on the length of time that glochidia are retained in the gills of the female. Bradytictic, or long-term brooders, typically spawn in late summer, brood young over the winter, and release mature glochidia during the following spring or early summer. Tachytictic, or short-term brooders, typically spawn in the spring and release mature glochidia sometime during that summer.

Once maturity is reached, the glochidia are released into the water column through the female's excurrent aperture, from specialized gill pores, or by rupture of the ventral portion of the gill (McMahon 1991). Once released by the female, glochidia passively drift with the currents until they attach to suitable host fishes or die. Mechanisms promoting glochidia-fish contact include respiratory, feeding, and spawning activities of fishes, as well as specialized morphologies and behaviors of particular mussel species (Kraemer 1970, Dartnall and Walkey 1979, Zale and Neves 1982). Attachment occurs on the gills, fins, or scales, depending on the mussel subfamily, and is followed by encystment and metamorphosis into juveniles. Metamorphosis generally occurs over a period of 1-3 weeks (Neves 1991) but can last for a few months (Zale and Neves

1982). Once metamorphosis is complete, the juvenile mussel drops from the host fish, settles into the surrounding substrata, and, if conditions are suitable, grows until sexual maturity occurs. Then, the reproductive cycle is repeated. During a mussel's reproductive years, growth rates are reduced, since significant energy and nutrients are required to produce young.

Unlike unionids, sphaeriid clams are ovoviviparous, self-fertilizing hermaphrodites. All species brood developing embryos in specialized chambers where maternal nutrients are supplied to the embryos. After maturity is reached, the once developing embryos are released into the water column as miniature adults. Due to their relatively large size as mature embryos, compared with other freshwater bivalves (Mackie 1984), most juvenile sphaeriids disperse between drainage systems by clamping their shells onto things such as aquatic insects (McMahon 1991), feathers of waterfowl (Burky 1983), or the limbs of salamanders (Davis and Gilhen 1982) rather than dispersal by water currents. Given highly variable reproductive success rates, sphaeriids typically have 1-3 reproductive efforts per year (McMahon 1991). *Corbicula fluminea* reproduces in much the same manner as sphaeriid clams but tends to use the water currents as its primary means of dispersal (Williams and McMahon 1986). Most populations of the Asian clam have 2 reproductive efforts per year, one in the spring and the second in the late summer (McMahon 1983a).

Habitat Requirements

Freshwater mussels occur in a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with unionids generally being most successful and prevalent in stable, coarse sand, or sand-gravel mixtures (Way et al. 1990a). Water velocity also plays a critical role in the distribution, diversity, and abundance of mussel populations. Unionids tend to thrive in conditions where water velocities are low enough to allow for substrata stability, but high enough to prevent excessive siltation (Way et al. 1990a). Water velocity also affects the amount of nutrients carried to the filter-feeding organisms. Chemical parameters such as pH and calcium concentrations can influence the distributions of mussel populations as well. The majority of species prefer alkaline water with a pH above 7.0, but unionids can grow and reproduce over a pH range of 5.6 - 8.3 and can tolerate acidic conditions as low as 4.7 (Okland and Kuiper 1982). Typically, habitats of low pH also have low calcium concentrations. Low calcium concentrations can lead to poor growth and shell dissolution in some individuals, especially if the shell is worn (Kat 1982). Given that growth and dissolution rates are affected by many factors other than pH and calcium concentrations, the minimum tolerable values can vary significantly among habitats. Another important factor to mention in the viability of freshwater mussel populations is the need for suitable host fishes. If the proper host fish is not present for a particular mussel species at any given location, then eventually this species will become extirpated from the site regardless of the habitat conditions.

Sphaeriid clams and Asian clams are generally more tolerant than unionids of what we consider to be harsh conditions. Unlike many unionids, the diversity and abundance of some *Pisidium* and *Sphaerium* species are inversely correlated with substrata size (Kilgour and Mackie 1988), which may be associated with sediment organic feeding mechanisms. *Corbicula fluminea* has a much broader substrata range, and has been seen to successfully colonize habitat consisting of bare rock outcrops to habitat with high silt loads. The highest abundances of *C. fluminea* in

North Carolina are often associated with sandy disturbed habitats or with lotic habitats below dams (J.M. Alderman, NC Wildlife Resources Commission, pers. comm.). Sphaeriids have the ability to colonize ponds and lakes where the depth is greater, the flow is negligible, and the sediment and organic loads are high. Again, this may be associated with feeding mechanisms in sphaeriid clams. Chemical parameters such as pH and calcium concentration regulate sphaeriid clams and *C. fluminea* populations in much the same manner that they affect unionid populations.

Taxonomy, Distributions, and Statuses

Freshwater mussels are represented worldwide, with North America containing the largest collection - 297 currently recognized species and subspecies (Williams et al. 1993). While unionids are distributed across the entire continent, the greatest diversity lies within the southeastern United States (Neves et al. 1997). North Carolina's share of this diversity is impressive. Once our taxonomic understanding is more complete, approximately 70 species are expected to occur in our state. A significant amount of literature describing site locations for unionids across North America has led to a more refined understanding of the distribution and taxonomy of this fauna.

Of the 297 recognized taxa of freshwater mussels in North America, Williams et al. (1993) recommended that 213 (72%) be considered endangered, threatened, or of special concern. Nearly half of North Carolina's freshwater mussel species are state listed as endangered, threatened, or special concern, and approximately 30% have undetermined statuses (J.M. Alderman, NCWRC, pers. comm.).

Sphaeriid clams are widely distributed and are represented in North America by approximately 38 species (Burch 1975, Turgeon et al. 1998). In North Carolina, there are approximately 13 species (Adams 1990). No species is currently listed at this time.

Anthropogenic effects, such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration are negatively affecting these taxa. With the introduction of exotic species, such as *C. fluminea*, and the impending introduction of *Dreissena polymorpha* (zebra mussel), the situation continues to worsen. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The freshwater mussel and sphaeriid clam survey of Gull Rock Game Land and Pungo River Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points. Since most waterways were canals, ditches, or swamps, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Freshwater mussels were surveyed using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). In areas where water clarity allowed, freshwater mussels were surveyed by viewing the substrata through the water surface with the naked eye. These areas also were surveyed with a view scope depending on the depth of the water. In areas that were turbid or tannic, freshwater mussels were collected by tactilely surveying suitable habitat. Freshwater mussels also were surveyed at sites by sieving the substrata through a dip net or raking the substrata. Tactile, dip net, and rake searches were the dominant survey techniques utilized due to the conditions of the waterways associated with the game lands. If a live mussel or shell was located, we typically performed a tactile timed search in the area to determine an approximate abundance at each site. Any mussel specimens collected were identified to species, measured for length (mm) if possible, and kept for curation. Brackish water bivalves and barnacles also were collected in much the same manner, and were identified according to Gosner (1978) and Porter and Houser (1997). All common and scientific nomenclature follows Turgeon et al. (1998).

Sphaeriid clams were collected using a variety of methods, including dip netting and tactile searches. The most prevalent method used was dip netting. This involved running a 1/8-inch mesh dip net through vegetation and the substrata to search for the clams. Most specimens collected were preserved in 70% ethanol and identified according to Burch (1975). Specimens also were sent to Dr. Gerald L. Mackie, University of Guelph, Ontario, Canada, for identification confirmation. All common and scientific nomenclature follows Turgeon et al. (1998).

For each taxon, a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Gull Rock Game Land

Over 5 days from 6 June to 12 July 2000, 25 sites were surveyed, (sites 11 and 21 were not surveyed for unionids) and freshwater mussels were not collected or observed in any of the waterways associated with Gull Rock Game Land. The SES for mussels was 1.98. Over the same time period and at 26 sites (site 11 not surveyed), sphaeriid clams were observed at only 1 site (Figure 2a and Table 2a), with an overall SES score of 2.63. Nearly two-dozen specimens of *Musculium partumeium* (swamp fingernailclam) were present at this site, with no evidence of reproduction. The swamp fingernailclam was collected from substrata comprised of detritus and silt.

In addition to the unionids and sphaeriids, a few species of brackish water organisms were collected. These species included *Rangia cuneata* (wedge rangia), *Mulinia lateralis* (dwarf surfclam), *Mytilopsis leucophaeata* (dark falsemussel), *Tagelus plebius* (stout tagelus), and *Balanus balanoides* (northern rock barnacle) (Table 2b).

Pungo River Game Land

Over 2 days from 12 July to 13 July, 12 sites were surveyed, (sites 3 and 4 were not surveyed for unionids) and freshwater mussels were found at only 1 site (Figure 2b and Table 2c). A fresh-dead piece of shell from *Utterbackia imbecillis* (paper pondshell) was the only evidence of unionids in the waterways associated with the game land. The SES for mussels was 2.5. Over the same time period and at all 14 sites, sphaeriid clams were observed from only 2 sites (Figure 2c and Table 2d), with an overall SES of 3.14. Two species were collected during the inventory: *Musculium partumeium* (swamp fingernailclam) and *Corbicula fluminea* (Asian clam). The swamp fingernailclam was collected from areas of detritus and silt and was rare at both sites, but reproduction was evident. The Asian clam was collected in sand at one of the sites with *M. partumeium*, but it was common and reproduction was evident.

In addition to the unionids and sphaeriids, a few species of brackish water organisms were collected. These species included *Rangia cuneata* (wedge rangia), *Mytilopsis leucophaeata* (dark falsemussel), and *Balanus balanoides* (northern rock barnacle) (Table 2e).

Discussion

The overall diversity of the freshwater mussel fauna in Gull Rock Game Land and Pungo River Game Land and their associated waterways is low. Further comparisons to other waterways within this portion of the Tar-Pamlico Basin are hampered due to a lack of surveys. A search of the NCWRC Nongame database did indicate that a total of 20 freshwater mussel species have been collected from the Tar-Pamlico River Basin over the past 15 years. However, most of these surveys were conducted in the northern to central portions of the river basin (e.g., Warren, Halifax, Edgecombe counties) where the waterways are markedly different than those found in Hyde County. Likewise, Johnson (1970) lists a total of 12 species present in the Pamlico River Basin, but these species are likely present in the upper portions of the river basin based on the NCWRC Nongame database information.

Current distribution patterns and ranges of the sphaeriid fauna are much less understood than those for the freshwater mussel fauna. The location of 1 sphaeriid species (excluding *Corbicula fluminea*) at 3 sites is low when compared to additional statewide aquatic inventories conducted by the authors. A search of the NCWRC Nongame database did not return any results from this portion of the Tar-Pamlico River Basin for comparison.

The water body types encountered during our survey were somewhat homogeneous, with most sites representing ditches and canals. Likewise, given the proximity of the survey area, most of the waterways surveyed appeared to be brackish given some of the species collected. Given the narrow range of available habitat types and the presence of brackish water, it was not surprising that we discovered only a single shell of *Utterbackia imbecillis* from the upper portion of the Pungo River. It is likely that individuals of this species occur in the headwaters of the river, where brackish water is less of an influence. Given these factors, it was not surprising to find a relatively low number of sphaeriid species as well. It also is likely that the influence of geomorphologic and topographic factors have significantly affected the current unionid and sphaeriid fauna. Major landscape scale factors such as these are known to influence and impact the distributions and abundances of organisms over time, and it is possible that the area we

surveyed has a naturally low presence of freshwater bivalves. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture and logging within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration and sedimentation. The practice of ditching for drainage purposes was commonly evident and also has likely had a significant effect on the current freshwater bivalve composition of the area. With the SES ranging from 2 to 2.5 for freshwater mussels, it also is possible that our survey efforts somewhat influenced the poor diversity results. On the other hand, with the SES at approximately 3 for sphaeriids, we likely captured a representative sample of the area's diversity.

While no imperiled freshwater bivalve species were collected during this survey, continual research and status surveys are needed to determine the present status of this group. *Musculium partumeium* is currently considered a species of undetermined status (Adams 1990), but recent surveys by the authors have shown this species to be common across the Coastal Plain and parts of the Piedmont. Current land management practices, including agriculture and urbanization, are having an effect on the bivalve fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

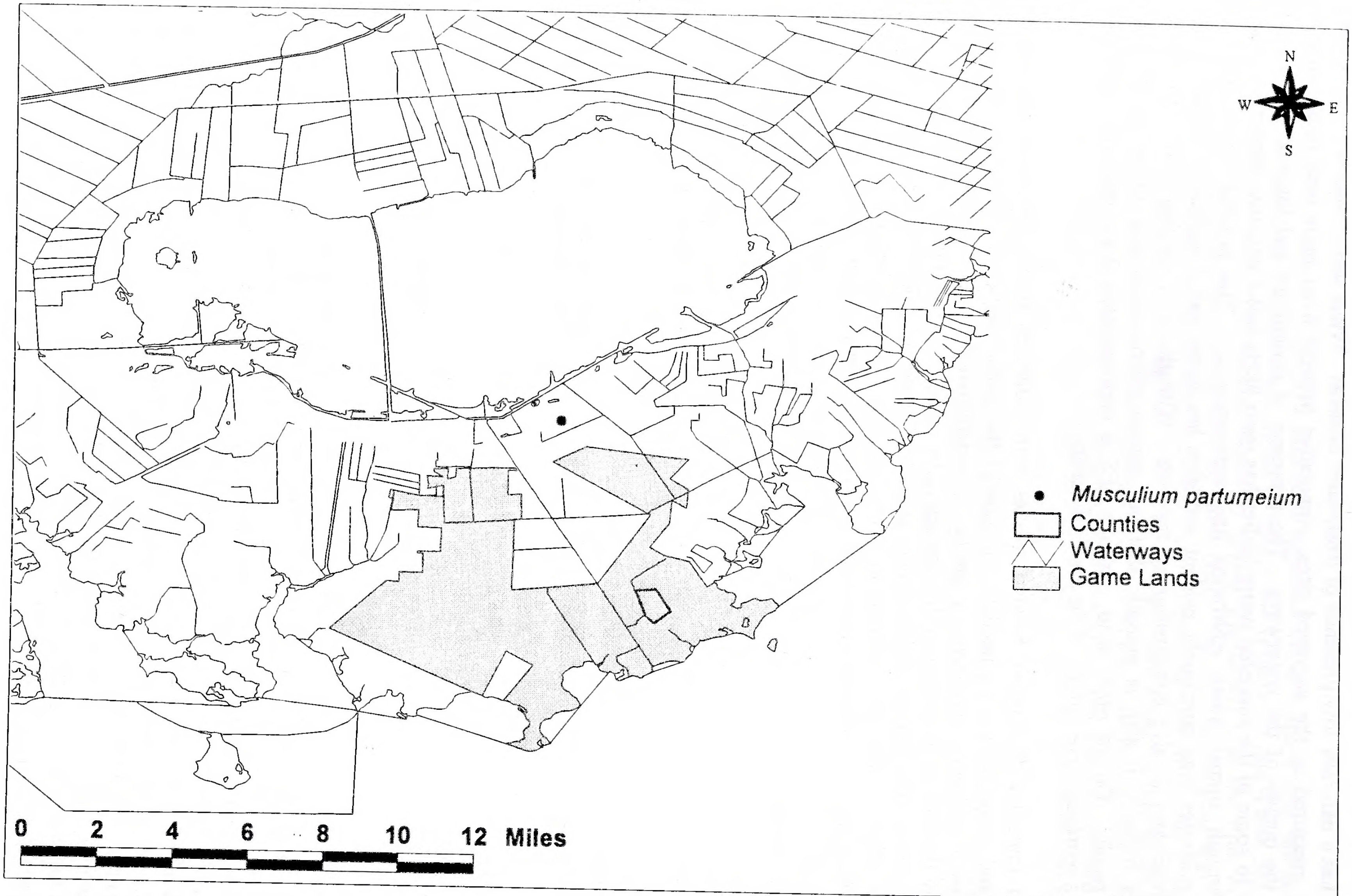

Figure 2a. Map of sites indicating where each species of sphaeriid clam was collected in the Gull Rock Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 2a. Sphaeriid clam species found in Gull Rock Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Musculium partumeium							
000608.6btw	6/8/2000	Gull Rock Game Land	Hyde	Swamp near Rose Canal	US 264	present	B.T. Watson

Table 2b. Brackish water species found in Gull Rock Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Balanus balanoides							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	common	B.T. Watson
Mulinia lateralis							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	present	A.E. Bogan, B.T. Watson
Mytilopsis leucophaeata							
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	uncommon	B.T. Watson, A.E. Bogan
Rangia cuneata							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	present	B.T. Watson, A.E. Bogan
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	present	B.T. Watson
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	present	B.T. Watson
Tagelus plebius							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	present	B.T. Watson

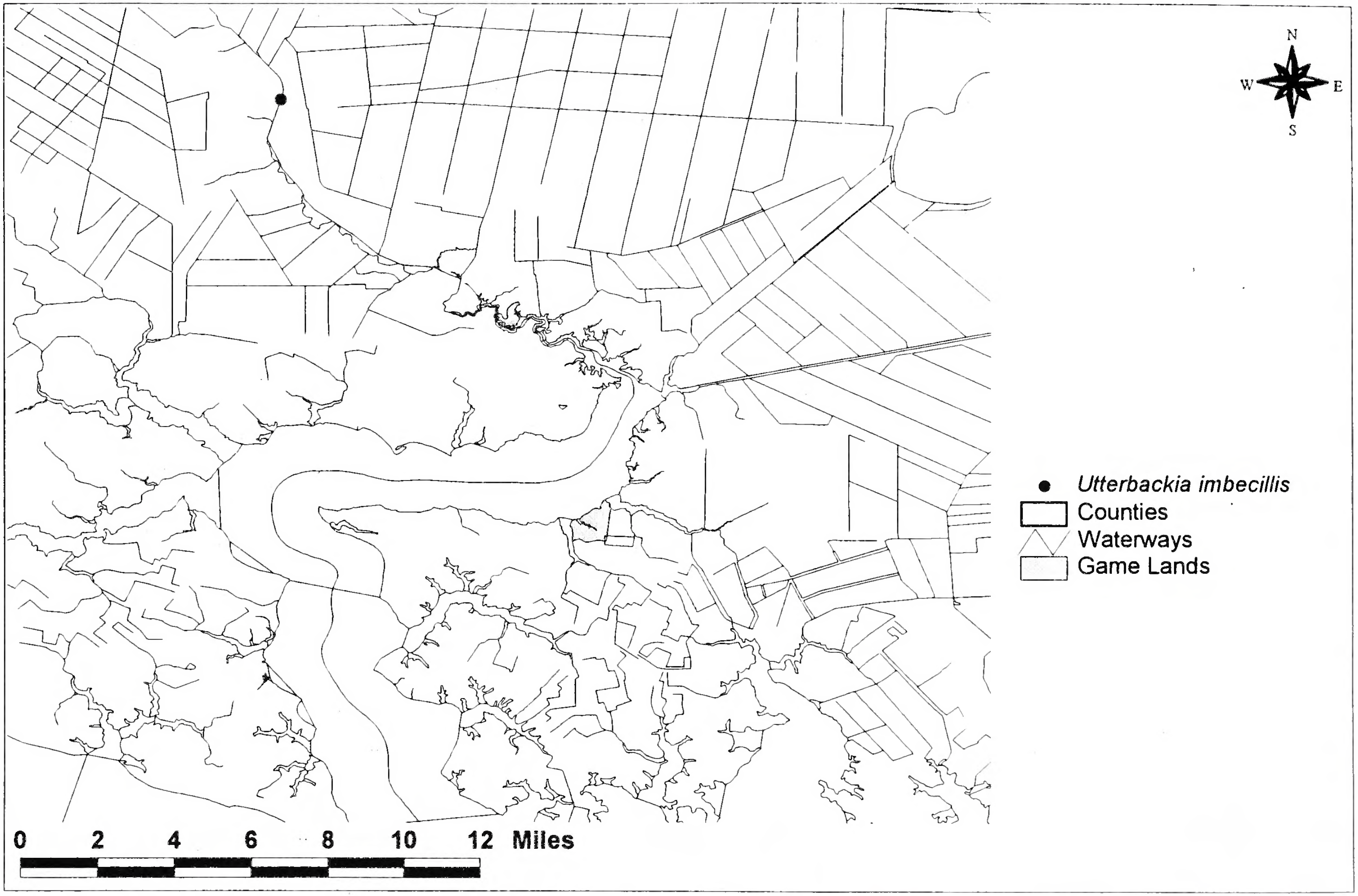

Figure 2b. Map of sites indicating where each species of freshwater mussel was collected in the Pungo River Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 2c. Freshwater mussel species found in Pungo River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Utterbackia imbecillis							
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	rare	B.T. Watson, A.H.. Fullerton

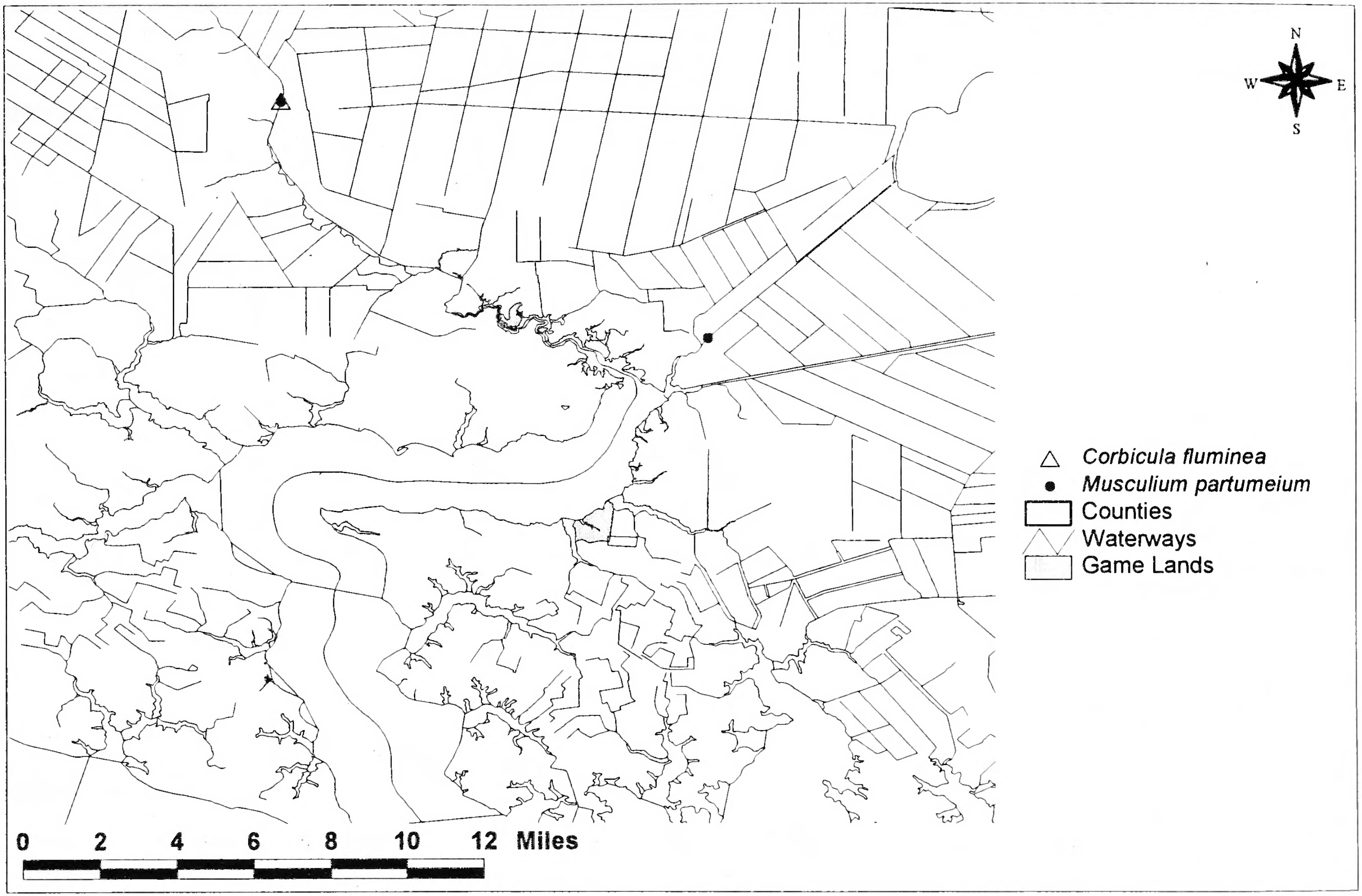

Figure 2c. Map of sites indicating where each species of sphaeriid clam was collected in the Pungo River Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 2d. Sphaeriid clam species found in Pungo River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Corbicula fluminea							
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	common	B.T. Watson
Musculium partumeium							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	rare	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	rare	B.T. Watson

Table 2e. Brackish water species found in Pungo River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Balanus balanoides							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	present	J.E. Cooper, B.T. Watson
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	rare	B.T. Watson
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	patchy uncommon	J.E. Cooper, B.T. Watson
000713.1btw	7/13/2000	Pungo River Game Land	Hyde	Canal to Rose Bay	US 264 0.4 mi NW SR1139	uncommon	B.T. Watson
Mytilopsis leucophaeata							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	patchy uncommon	B.T. Watson, A.E. Bogan
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	common	B.T. Watson, A.E. Bogan
Rangia cuneata							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	common	B.T. Watson
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	uncommon	B.T. Watson
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	rare	B.T. Watson
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	rare	B.T. Watson
000713.1btw	7/13/2000	Pungo River Game Land	Hyde	Canal to Rose Bay	US 264 0.4 mi NW SR1139	present	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	present	B.T. Watson
000713.6btw	7/13/2000	Pungo River Game Land	Beaufort	Lower Dowry Creek	NC 264/Bike 2	present	B.T. Watson

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AQUATIC SNAILS

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Introduction

Freshwater snails (Mollusca: Gastropoda) are among the most ubiquitous organisms of shallow littoral zones in lakes and streams. Due to their behavior, widespread distribution, and commonly high abundance, snails serve a number of important roles in aquatic ecosystems. These include driving predator-prey interactions (Vermeij and Covich 1978, Lodge et al. 1987), serving as a dietary component to fish and wildlife, acting as water quality indicators, and most importantly, grazing on nuisance algae and detritus. However, freshwater snails are often overlooked in part due to their small size, perceived lack of charisma, cryptic habits, and the lack of readily available comprehensive guides for identification. As part of the inventory of aquatic animals associated with the state-owned Gull Rock Game Land and Pungo River Game Land, we conducted field surveys of aquatic snails found in waterways occurring in and around the game lands to better understand the taxonomy, distribution, and conservation needs of the taxa in North Carolina.

Life History

Much information about the reproductive cycles of freshwater snails has been ascertained due to the ease of laboratory rearing. From this information, 2 typical categories have been developed in which snails can be placed reproductively (Russell-Hunter 1978, Calow 1978). The first category includes annual adults that reproduce in the spring and die (semelparous). Most pulmonates (lung breathing), which are oviparous hermaphrodites, belong to this group including the genera *Lymnaea* and *Physa*. The second category includes perennial adults that reproduce in both spring and late summer. Most prosobranchs (gill breathing), which are dioecious and can be oviparous or ovoviviparous, belong to this group. These species are iteroparous and often live and reproduce for 4-5 years. Prosobranchs also are often sexually dimorphic, with females living longer than males (Brown et al. 1989).

Habitat and Food Requirements

Freshwater snails occupy a variety of habitat types, including both lentic (e.g., lakes, ponds, reservoirs) and lotic (e.g., rivers, streams, creeks) systems. Habitat preferences tend to be species specific, with well-documented substratum selection (Brown 1991). In general, silty habitats with slow-moving currents are colonized predominately by pulmonates or detritivorous prosobranchs, whereas limpets or prosobranch grazers colonize fast-current localities (Harman 1972). Many biotic and abiotic factors regulate the distribution of freshwater snails, with water hardness and pH considered to be the major determinants (Macan 1950, Pip 1986). However, it has been suggested that physiochemical factors such as calcium concentrations may only act to limit successful invasion of habitats with extreme levels of these factors (Lodge et al. 1987).

Other factors such as dispersal ability and adequate substrata may play a more prominent role in snail distribution.

Freshwater snails are predominantly herbivores or detritivores, although they can ingest carrion (Bovbjerg 1968) or passively consume small invertebrates associated with periphyton (Cuker 1983a). Apparently, they prefer periphyton because it is easier to scrape than macrophytes, and it contains higher concentrations of nitrogen and other limiting nutrients (Russell-Hunter 1978, Aldridge 1983). Algae and diatoms also are prominent sources of nutrients for freshwater snails (Lodge 1986). While macrophytes are not the preferred source of nutrients for most freshwater snails, significant consumption can occur if snail densities reach high levels (Sheldon 1987).

Taxonomy, Distribution, and Statuses

Freshwater snails are divided into 2 groups – prosobranchs and pulmonates. Prosobranch snails are gill breathing and have a calcareous plate called an operculum that seals the aperture when the snail withdraws into its shell. Pulmonate snails are lung breathing and lack an operculum. Of the approximately 500 species recognized in North America, there are 49 genera and 349 species of prosobranch snails and 29 genera and 150 species of pulmonate snails (Burch 1982). While snails are widespread across the continent, they have reached their greatest abundance and diversity within the streams of the southeastern United States (Brown 1991). In North Carolina, there are approximately 52 species representing 10 families (Bogan 1997). Since very little work has been done to monitor freshwater snail populations, the current status of many species within North Carolina is undetermined. It is unknown as to the magnitude of impact that anthropogenic effects such as siltation, riparian habitat destruction, impoundments, pollution, and hydrologic regime alteration have had on the state's snail fauna. Therefore, it is crucial that nongame biologists continue to gather information pertaining to these organisms so proper management plans can be implemented.

Methods

The aquatic snail survey of Gull Rock Game Land and Pungo River Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points. Since most waterways were canals, ditches, or swamps, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Freshwater snails were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common methods used to sample the snail fauna were visual searches and dip netting. The visual search basically involved examining rocky substrata, woody debris, vegetation, cans and bottles, and other items that snails might colonize. Dip netting involved running a 1/8-inch mesh dip net through vegetation and the substrata to collect snails. Other techniques used to collect snails included tactile searches, the use of a viewscope, and raking of the substrata. Habitat preference, relative abundance, and recent reproduction for snail species were noted at each site. Snails were

preserved in 70% ethanol and identified according to Burch (1989) and Basch (1963). Scientific names are according to Turgeon et al. (1998). Dr. Arthur E. Bogan, curator of aquatic invertebrates at the NC State Museum of Natural Sciences, verified some of the species identifications. Not all snails collected were preserved for obvious conservation and ethical reasons.

For aquatic snails, a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Gull Rock Game Land

Over 5 days from 6 June to 12 July 2000, 26 sites were surveyed, (site 11 was not surveyed for snails) and aquatic snails were collected or observed at 14 localities (Figure 3a). At least 6 species representing 5 families were documented during the Gull Rock Game Land survey (Tables 3a and 3b). Due to the difficulty of identifying hydrobiids (see Discussion), we have identified all specimens to family for this report. The relative abundance of each species varied, but the most abundant and widespread species were *Physella* sp. and *Ferrissia* sp., with the snails residing at 8 and 7 sites, respectively (Figure 3a). Due to species level variation and the uncertainty of positively discerning *Ferrissia* specimens, all specimens of this genus were identified as *Ferrissia* sp. Likewise, all *Physella* specimens were identified to genus only, since the soft parts were not examined. The remaining snail species were represented over a smaller number of sites, ranging from 1-4. Regardless of the number of sites from which a particular species was collected, abundances were typically rare to uncommon over the entire surveyed range. Recent reproduction was seen sparingly at a number of sites for a few of the snail species collected during the survey. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and Hydrobiidae), it was difficult to confirm whether these were adults or juveniles, and typically reproduction was not recorded. The SES for aquatic snails was 3.06.

Ferrissia sp., *Micromenetus dilatatus* (bugle sprite), *Gyraulus deflectus* (flexed gyro), and Hydrobiidae were typically found in areas with slow to moderate flow on aquatic vegetation, detritus, and woody debris. These species also were found on cans and bottles.

Physella sp. (physa snail) and *Pseudosuccinea columella* (mimic lymnaea) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the channel bank, or wherever the conditions were swamp-like. Both species typically were found on aquatic vegetation and woody debris, while occasionally residing along the clay and mud banks.

Pungo River Game Land

Over 2 days from 12 July to 13 July, 14 sites were inventoried and aquatic snails were collected or observed at 9 localities (Figure 3b). At least 8 species representing 5 families were documented during the Pungo River Game Land survey (Tables 3c and 3d). Due to the difficulty

of identifying hydrobiids (see Discussion), we have identified all specimens to family for this report. Likewise, *Ferrissia* and *Physella* specimens were identified to genus only. The relative abundance of each species varied, but no species was dominant in the area. Overall, the number of sites occupied by all the species was small, ranging from 1-5 sites, with a single site providing suitable habitat for 6 of the 8 species. Regardless of the number of sites from which a particular species was collected, abundances were typically rare to uncommon over the entire surveyed range. Recent reproduction was seen sparingly at a number of sites for a few of the snail species collected during the survey. Due to the minute size of some of the species (e.g., *Micromenetus dilatatus* and Hydrobiidae), it was difficult to confirm whether these were adults or juveniles, and typically reproduction was not recorded. The SES for aquatic snails was 3.36.

Ferrissia sp., *Laevapex fuscus* (dusky ancylid), *Micromenetus dilatatus* (bugle sprite), *Gyraulus deflectus* (flexed gyro), and Hydrobiidae were typically found in areas with slow to moderate flow on aquatic vegetation, detritus, and woody debris. These species also were found on cans and bottles.

Physella sp. (physa snail), *Pseudosuccinea columella* (mimic lymnaea), and *Planorbula armigera* (thicklip rams-horn) also tended to inhabit areas with slow to moderate flow, which included backwater areas, along the channel bank, or wherever the conditions were swamp-like. The physa snail and mimic lymnaea typically were found on aquatic vegetation and woody debris, while occasionally residing along the clay and mud banks. The thicklip rams-horn was found in detritus at a single site that was a swamp.

Discussion

Overall, the diversity and abundance of freshwater snails in the waterways associated with Gull Rock Game Land and Pungo River Game Land appear to be relatively low when compared to additional statewide aquatic inventories conducted by the authors. Further comparisons are hampered due to a lack of survey information for this part of the state. Given the relative lack of diverse habitat types and flow regimes encountered, and the apparent high number of brackish water stream miles in this portion of the Tar-Pamlico River Basin, it was not surprising that we found a lack of gastropod diversity. Likewise, these factors may have been the primary dynamic contributing to their limited distribution and low abundance. It also is likely that the influence of geomorphologic and topographic factors have significantly affected the current gastropod fauna. Major landscape scale factors such as these are known to influence and impact the distribution and abundance of organisms over time. While water chemistry parameters were not measured at the surveyed sites, cumulative impacts from poor land uses could be affecting the quality of the waterways. The presence of agriculture within close proximity to some of the surveyed water bodies has most likely had a negative impact on stream quality through animal waste infiltration and sedimentation. Effects from urbanization were minimal, since most of the river basin is rural. Since the SES was over 3.0 for both game lands, our survey efforts were relatively sufficient to have captured an accurate reflection of the aquatic snail composition of the area.

Taxonomic uncertainties within the freshwater snail fauna make the results here subject to revision. For example, the differentiation between *F. rivularis* and *F. fragilis* is difficult due to shell shape variation. Therefore, a common factor used to distinguish these species is the habitat they are collected in, with *F. rivularis* colonizing rivers and streams and *F. fragilis* inhabiting

stagnant areas such as ditches, ponds, and backwater areas (Burch 1989). All of the limpets identified in this survey were assigned to *Ferrissia* sp., but it is possible that at least both species inhabit some of the sites that were surveyed. Some of the *Ferrissia* sp. field identifications could also have been *Laevapex fuscus* given the difficulty in sometimes differentiating smaller specimens in the field. Likewise, many uncertainties exist as to the taxonomy of *Physella* and hydrobiids without examination of soft parts (Burch 1989). Since we did not preserve the specimens for the examination of soft parts, we identified *Physella* specimens to genus only and the hydrobiid identifications are tenuous.

While no threatened or endangered gastropod species was collected during the survey of Gull Rock and Pungo River game lands, continual research and status surveys are needed to determine the present status of each species. The status of *Gyraulus deflectus* is considered possibly imperiled but undetermined due to a lack of information (Adams 1990), which may be in part due to misidentification of the species given its small size. Current land management practices, including agriculture and urbanization, are having an effect on the snail fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

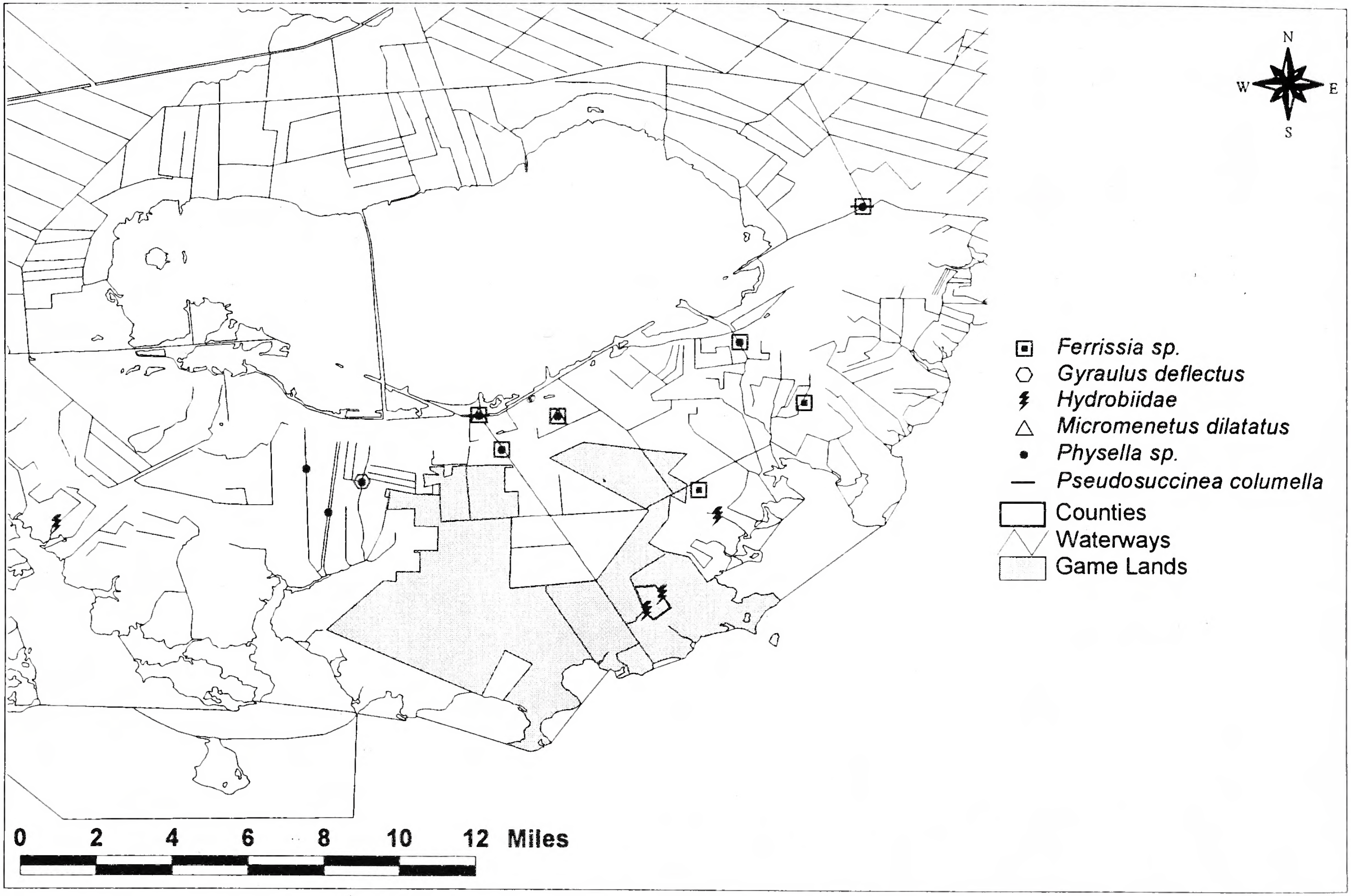

Figure 3a. Map of sites indicating where each species of aquatic snail was collected in the Gull Rock Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 3a. Aquatic snail species found in Gull Rock Game Land and associated waterways.

Prosobranchia	
Hydrobiidae	hydrobiid
Pulmonata	
Ancylidae	
Ferrissia sp.	limpet
Lymnaeidae	
Pseudosuccinea columella	mimic lymnaea
Physidae	
Physella sp.	physa snail
Planorbidae	
Gyraulus deflectus	flexed gyro
Micromenetus dilatatus	bugle sprite

Table 3b. Aquatic snail species found in Gull Rock Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
***Ferrissia* sp.**							
000607.3btw	6/7/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	rare	B.T. Watson
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	rare	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	patchy uncommon	B.T. Watson
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson
000608.1btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1110	rare	B.T. Watson
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	uncommon	B.T. Watson
000608.6btw	6/8/2000	Gull Rock Game Land	Hyde	Swamp near Rose Canal	US 264	patchy common	B.T. Watson
Gyraulus deflectus							
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	uncommon	B.T. Watson, A.E. Bogan
Hydrobiidae							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	patchy uncommon	B.T. Watson, A.E. Bogan
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	present	B.T. Watson, A.E. Bogan
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	uncommon	B.T. Watson, A.E. Bogan
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	patchy uncommon	B.T. Watson, A.E. Bogan
Micromenetus dilatatus							
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson
000608.6btw	6/8/2000	Gull Rock Game Land	Hyde	Swamp near Rose Canal	US 264	patchy uncommon	B.T. Watson
***Physella* sp.**							
000607.3btw	6/7/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	uncommon	B.T. Watson
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	rare	B.T. Watson
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	rare	B.T. Watson
000608.6btw	6/8/2000	Gull Rock Game Land	Hyde	Swamp near Rose Canal	US 264	uncommon	B.T. Watson
000711.3btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay Creek (W)	SR 1121/Bike 2	rare	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	uncommon	B.T. Watson
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	common	B.T. Watson
Pseudosuccinea columella							
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	rare	B.T. Watson

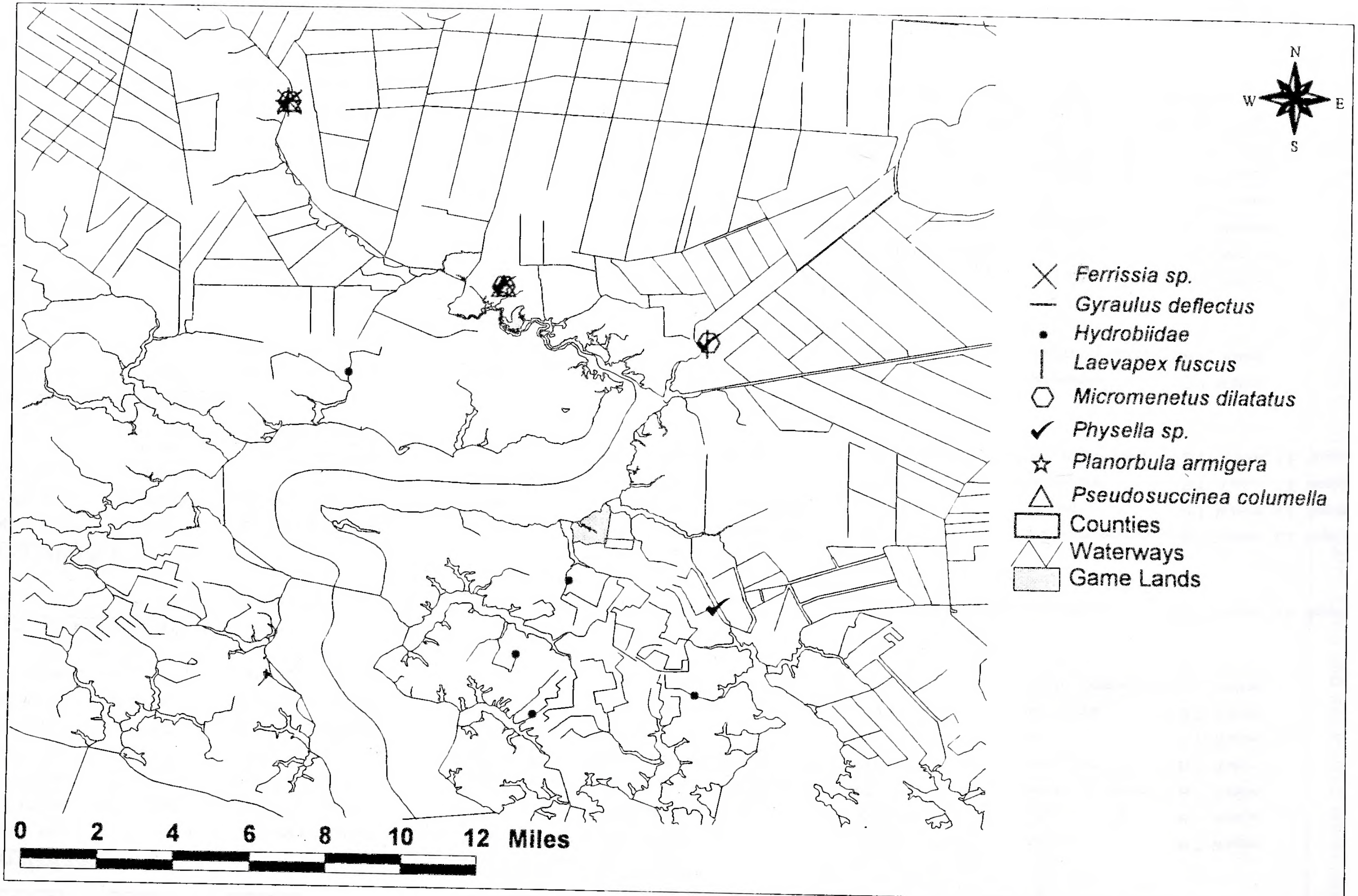

Figure 3b. Map of sites indicating where each species of aquatic snail was collected in the Pungo River Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 3c. Aquatic snail species found in Pungo River Game Land and associated waterways.

Prosobranchia	
Hydrobiidae	hydrobiid
Pulmonata	
Ancylidae	
Ferrissia sp.	limpet
Laevapex fuscus	dusky ancylid
Lymnaeidae	
Pseudosuccinea columella	mimic lymnaea
Physidae	
Physella sp.	physa snail
Planorbidae	
Gyraulus deflectus	flexed gyro
Micromenetus dilatatus	bugle sprite
Planorbula armigera	thicklip rams-horn

Table 3d. Aquatic snail species found in Pungo River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
***Ferrissia* sp.**							
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	common	B.T. Watson
Gyraulus deflectus							
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	present	B.T. Watson, A.E. Bogan
Hydrobiidae							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	patchy common	B.T. Watson
000712.4btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Smith Creek	SR 1143	rare	B.T. Watson, A.E. Bogan
000712.6btw	7/12/2000	Pungo River Game Land	Hyde	Canal (trib to?) S of Slade Creek	SR 1145	patchy abundant	B.T. Watson, A.E. Bogan
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	patchy uncommon	B.T. Watson, A.E. Bogan
000713.6btw	7/13/2000	Pungo River Game Land	Beaufort	Lower Dowry Creek	NC 264/Bike 2	patchy uncommon	B.T. Watson
Laevapex fuscus							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	rare	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	uncommon	B.T. Watson
Micromenetus dilatatus							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	rare	B.T. Watson
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	rare	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	patchy uncommon	B.T. Watson, A.E. Bogan
***Physella* sp.**							
000713.1btw	7/13/2000	Pungo River Game Land	Hyde	Canal to Rose Bay	US 264 0.4 mi NW SR 1139	rare	B.T. Watson
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	patchy common	B.T. Watson
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	uncommon	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	uncommon	B.T. Watson
Planorbula armigera							
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	common	B.T. Watson
Pseudosuccinea columella							
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	patchy common	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	common	B.T. Watson

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CRAYFISHES

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Introduction

Crayfish play important roles in aquatic and sometimes terrestrial ecosystems, both as food sources for many animals and as consumers of plant and animal material. Despite the magnitude of their ecological roles, we have much to learn about crayfish distributions, life histories, and taxonomy. As part of the inventory of aquatic animals associated with the state-owned Gull Rock and Pungo River game lands, we conducted field surveys of the crayfishes found in waterways occurring in and around the game lands to contribute to our understanding of the distribution and status of crayfishes in North Carolina.

Reproduction and Life History

The crayfishes that occur in North Carolina (all members of the family Cambaridae) live for 2-3 years, on average (Hobbs III 1991, Taylor et al. 1996). Energy obtained from food consumption is allocated largely toward growth as juveniles and toward reproduction as adults (DiStefano 1993). Growth is accomplished through a series of exoskeletal molts (a process known as ecdysis), numbering from 5-10 until adulthood is reached, followed by only 1 (females) or 2 (males) molts per year on average throughout adulthood (Hobbs III 1991, DiStefano 1993). Male cambarid crayfishes exhibit cyclic dimorphism, alternating between a reproductively active form (form I) and a non-reproductive form (form II). Form I males can be present all year, but are usually most abundant during the fall and/or spring. Females carry fertilized eggs attached to their abdomens (a condition that is termed "in berry") for 2-20 weeks, depending on water temperatures. Once hatched, the juveniles are carried on the female until they molt into the 3rd instar (on average), after which they are free-living. Cambarid crayfishes breed more than once during their lives (Hobbs III 1991, DiStefano 1993).

Habitat Requirements and Preferences

Crayfish occur in lentic (e.g., lakes, ponds, marshes, ditches, backwaters of large rivers, groundwater) and lotic (e.g., streams, rivers, groundwater) aquatic habitats ranging from oligotrophic to hypereutrophic (Hobbs III 1991). Crayfish can be further classified as hypogean (below-ground dwellers) or epigean (above-ground dwellers). Hypogean crayfish spend much of their time in elaborate underground burrows associated with groundwater. These burrows can be in close proximity to a water body or stream, but can also be situated far from open water. Depending on the amount of time spent underground and the extent of tunnels created, burrowing crayfish are classified as primary, secondary, or tertiary burrowers (Hobbs III 1991). Generally, epigean crayfish occur in shallow (1-2 m) water, but can occur in deeper water, especially as adults. Juveniles are often found in littoral areas, where adequate shelter provides protection from predation and may mediate competition with adults. Crayfish actively forage at night, but seek shelter from predators during daylight in aquatic macrophytes, leaf litter, woody

debris, overhanging roots, cobble or large boulders, burrows or depressions, and in human debris (e.g., cans, tires) (Lodge and Hill 1994).

Crayfish are affected by both water and habitat quality. Changes in water quality that interfere with respiration (e.g., drastic temperature changes, acidification, pollution) can be detrimental to crayfish populations. Many crayfish are oxygen regulators and can survive changes in oxygen levels (Reiber 1995), but some are oxygen conformers and are less likely to successfully contend with these changes (Hobbs III 1991). Water pollution, caused by sources such as sewage, agricultural and urban runoff, acidification, and auto exhaust, can result in bioaccumulation of pesticides and trace heavy metals (e.g., lead, copper, cadmium). This can harm animals that consume crayfish in addition to directly causing negative effects on crayfish (e.g., mutation, reproductive failure, death) (Taylor et al. 1995, Daveikis and Alikhan 1996, Anderson et al. 1997, Zaranko et al. 1997). Habitat destruction can also negatively affect crayfish populations. Land use practices (e.g., agriculture, logging, development) can alter habitat resulting in fewer areas available as shelter to crayfish (Smith et al. 1996, Richter et al. 1997). For example, siltation and runoff can decrease macrophyte (a source of food and shelter) availability, and channelization can alter stream bed sculpture.

Ecological Interactions

Crayfish are both directly and indirectly linked to the ecosystems in which they live. Because they are omnivorous (i.e., consume both plant and animal food, living or dead), and because they are consumed by animals from various trophic levels, crayfish form multiple links in aquatic and terrestrial food webs (Lodge et al. 1994, Charlebois and Lamberti 1996, Nystrom et al. 1996). Thus, crayfish are involved in the transfer of large amounts of energy in these systems. Crayfish process nutrients and make them available to other animals by (1) breaking down large material via shredding into smaller sizes, and (2) converting nutrients into biomass. Crayfish feed on aquatic vegetation (e.g., macrophytes, algae, periphyton), macroinvertebrates (e.g., aquatic insects, mollusks, small crustaceans), and small vertebrates (e.g., amphibians, small/juvenile fish). Crayfish also consume nonliving organic matter such as leaf litter or terrestrial animal carcasses from the riparian zone or shore and decaying aquatic plant and animal matter (Lodge and Hill 1994). Crayfish in turn are consumed by invertebrates (including other crayfish), fish, amphibians, reptiles, birds, and mammals (Lodge and Hill 1994). Crayfish perform an important role as a member of symbiosis with many invertebrates and as host to various aquatic parasites (Lodge and Hill 1994). Crayfish also experience competition, both between species and among different sizes of individuals within a population (Lodge and Hill 1994).

The introduction of non-indigenous crayfishes to areas currently occupied by native crayfishes can result in competition or even extirpation of natives and can have impacts on other components of the ecosystem (Charlebois and Lamberti 1996, Perry 1998). For example, if crayfish become too abundant, they can be destructive to aquatic ecosystems by destroying more macrophytes than they consume, resulting in less habitat and food for other animals (Lodge et al. 1994, Nystrom et al. 1996). In fact, Lodge et al. (2000) consider nonindigenous crayfish introductions to be the single greatest threat to native crayfish biodiversity worldwide.

Taxonomy, Distribution, and Statuses

In the United States and Canada, approximately 350 taxa of crayfish are recognized (Taylor et al. 1996, J.E. Cooper, NC State Museum of Natural Sciences, Curator of Crustaceans, pers. comm.). However, many species still await description (J.E. Cooper, NCSM, pers. comm.). For example, several current species are now recognized to be species complexes consisting of more than a single taxon. Conversely, animals grouped into several species or subspecies by different authors may actually belong to the same species. The greatest diversity of crayfishes occurs in the Southeast (Hobbs III 1991, Taylor et al. 1996), and North Carolina harbors at least 33 native (possibly up to 46) and 3 introduced species of *Cambarus, Procambarus, Orconectes,* and *Fallicambarus* (Cooper and Braswell 1995, J.E. Cooper, NCSM, pers. comm.). About half of the described crayfishes in North Carolina are of undetermined conservation status due to a lack of data on the distribution and abundance of these animals. Additionally, there are perhaps as many as a dozen native species yet to be described (J.E. Cooper, NCSM, pers. comm.). Of those species for which we have at least some information, the North Carolina Natural Heritage Program lists 10 species as significantly rare (LeGrand and Hall 1998), and the Scientific Council on Freshwater and Terrestrial Crustaceans proposes that 8 of North Carolina's species be of special concern, and that 13 species be put on a watch list (Clamp 1999). New information about current distributions has recently been reported (Cooper and Braswell 1995, Cooper et al. 1998). However, given that undescribed species exist and that we have much to learn about the distributions of crayfishes in North Carolina, it is imperative that we continue to improve our knowledge of crayfish by contributing to the growing database.

Methods

The crayfish surveys of Gull Rock and Pungo River game lands were conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways were typically accessed at bridge crossings or roadside access points. Since most waterways were canals, ditches, or swamps, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Crayfishes were collected using a number of different techniques, depending on the conditions of the waterway being sampled (e.g., substrate type, depth of water). We collected crayfishes by hand or with dip nets from the substrate in which they were hiding (e.g., detritus, leaf packs, root wads, or under rocks). We trapped (minnow traps, set overnight) in Gull Rock Game Land. We also collected crayfishes by electrofishing at sites where conductivity was not too high to preclude using this method. Electrofishing and trapping generally proved to be a less successful method than dip netting. Collected specimens were preserved and stored in 70% ethanol.

Successful identification of many cambarid crayfishes usually requires collection of reproductive (form I) males. Certain features of their gonopods – the first pair of abdominal appendages, or pleopods – can be important in their taxonomy. Form I males can be distinguished from form II males by the advanced development of the terminal elements at the tips of their gonopods. In addition, form I males have highly developed hooks on the ischia of certain walking legs

(pereiopods) that are used to hold the female during copulation. The size and shape of their chelae may also vary at this stage. Some common characteristics used in identification of non-form I males are carapace length and depth/width ratio, areola width and length, presence and placement of spines, rostrum shape, color, and chela characteristics. Crayfishes were identified by using taxonomic keys (Cooper 1999 and Hobbs Jr. 1991) and a checklist (Hobbs Jr. 1989), by comparing individuals to reference collection specimens (North Carolina Wildlife Resources Commission, and North Carolina State Museum of Natural Sciences), and via personal communication with Dr. J.E. Cooper. Common names are according to Clamp (1999). As our understanding of crayfish taxonomy continues to improve, the identifications of the species we collected may change.

In addition to identifying individuals, we noted approximate abundances of each type of crayfish collected, and quantified average carapace lengths of those collected (from the tip of the rostrum to the posterior carapace edge). We also looked for evidence of recent reproduction and estimated habitat preferences of each species based on the areas from which they were collected. We recorded presence/absence data for each species encountered at each site visited to allow a crude estimate of the distribution of each species within the waterways associated with the game lands. These data will also be added to a larger database describing statewide distributions. Where possible, we recorded notes on ecological interactions (e.g., abundance of food, presence of competitors or predators, quality of habitat). For logistical and ethical reasons, we did not preserve every crayfish collected.

For crustaceans (crayfishes, crabs, and shrimps), a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Gull Rock Game Land

Over 5 days from 6 June to 12 July 2000, 27 sites were inventoried. Crayfish were collected or observed at 12 sites (Figure 4a and Table 4a). Crayfish were not observed at 15 sites. Three species of crayfish were collected during the survey period: *Cambarus (Lacunicambarus) diogenes* Girard, 1852, *Fallicambarus (Creaserinus) fodiens* (Cottle, 1863), and *Procambarus (Ortmannicus) acutus* (Girard, 1852). *Palaemonetes paludosus* (freshwater shrimp), *Callinectes sapidus* (blue crab), and *Uca minax* (brackish-water fiddler crab) were also collected during this survey. See Table 4b for statistics on carapace lengths of each species of crayfish collected. These calculations were performed on a sample only; we did not record measurements for every lot collected, nor on every individual per lot.

Cambarus (L.) diogenes (devil crayfish) was found at only 1 site. At this site, only 1 form II male was collected in a trap. Because this species is a primary burrower, it is likely that it is more common than our survey indicates. We noted the presence of a chimney burrow at 1 site. This burrow likely belonged to either *C. diogenes* or *F. fodiens*. This species had striking (but

apparently typical) coloration. The carapace was mostly slate blue-brown in color, but parts were an iridescent blue-black in the sunlight. Legs and undersides were pale blue, and all sutures and chelae edges were bright red. This species is considered stable and is found throughout much of the eastern Piedmont and Coastal Plain of this and other states.

Fallicambarus (C.) fodiens (no common name available) was found at only 3 sites (2 in the waterfowl impoundment and 1 in a canal), and was uncommon to common. However, this species is a primary burrower, so it is likely that it is more common than our survey indicated. We noted the presence of a chimney burrow at 1 site. This burrow likely belonged to either *C. diogenes* or *F. fodiens*. The presence of juveniles indicated that reproduction had recently occurred. Animals were collected from vegetation in shallow areas. We found only juveniles and subadults in open water, likely because adults remained in burrows. These animals were brown in color, with speckling on the carapace. One individual had abdominal stripes dorsally. This species is considered stable and is found throughout much of the eastern Piedmont and Coastal Plain of this and other states.

Procambarus (O.) acutus (White River crayfish) was the most common species encountered during the survey, yet was only present at less than half the sites surveyed. Abundance of this species varied across sites, but was rare to uncommon at most sites. Reproduction was evident, as juveniles were present at most sites. This species was collected from various types of habitat, but most often from detritus or vegetation in areas with slow flow. Juveniles were collected more often from shallow areas than were adults. This species is one of the largest *Procambarus* species occurring in North Carolina. Its coloration varies across its range. Generally, carapace color consists of different shades of tan, brown, and rust, but can also be olive green. Adornment includes dark speckling, cream mottling, and blurred stripes along carapace sides, and a wide dark stripe on the dorsal abdomen. This species is considered stable and is found throughout much of the Piedmont and Coastal Plain of this and other states.

Palaemonetes paludosus (freshwater shrimp) was collected from 14 sites. Animals were usually found in vegetation along banks. *Callinectes sapidus* (blue crab) was collected from muddy substrate at 9 sites, and *Uca minax* (brackish-water fiddler crab) was collected at 2 sites during this survey, presumably in water where salinities were higher than in freshwater.

Pungo River Game Land

Over 2 days from 12 to 13 July 2000, 14 sites were inventoried. Crayfish were collected or observed at 3 sites (Figure 4b and Table 4c). No crayfish were observed at 10 sites, and burrows only were observed at 1 site. Only 1 species of crayfish was collected during the survey period: *Procambarus (Ortmannicus) acutus* (Girard, 1852). *Palaemonetes paludosus* (freshwater shrimp), *Penaeus* sp. (southern commercial shrimp), *Callinectes sapidus* (blue crab), *Rhithropanopeus harrisii* (white-fingered mud crab), and an unidentified crab were also collected during this survey.

Procambarus (O.) acutus (White River crayfish) was found at only 3 of the 11 sites surveyed, and each sample consisted of only a few animals, most of which were juveniles. These animals were not measured nor curated. This species was collected from vegetation. This species is one of the largest *Procambarus* species occurring in North Carolina. For a description of its

coloration, see the section above for Gull Rock Game Land. This species is considered stable and is found throughout much of the Piedmont and Coastal Plain of this and other states.

We noted the presence of what appeared to be burrows at several sites (including 1 site where we collected no crustaceans). These burrows likely belonged to crabs, rather than to crayfishes.

Palaemonetes paludosus (freshwater shrimp) was collected from 7 sites. Animals were usually found in vegetation along banks. One individual *Penaeus* sp. (southern commercial shrimp) was collected at 1 site. *Callinectes sapidus* (blue crab) was collected at 1 site, *Rhithropanopeus harrisii* (white-fingered mud crab) was collected at 1 site, and an unidentified crab (not captured) was observed at 1 site during this survey. The commercial shrimp and crabs occurred in water that likely had higher salinities than freshwater.

Discussion

The overall diversity of crayfishes in this system was low, likely because a large portion of the survey area contained brackish water. *Procambarus acutus* was the most widespread species we encountered, but occurred at less than half of the sites surveyed and was generally uncommon. *Cambarus diogenes* and *Fallicambarus fodiens* were found at only 1 and 3 sites, respectively, in Gull Rock Game Land, and were not collected from Pungo River Game Land. The only crayfishes collected together were *F. fodiens* and *P. acutus*. The overall SES for Gull Rock and Pungo River game lands were 2.73 and 2.49, respectively, indicating that we likely obtained a fair representation of species present.

Aspects of crayfish communities can tell us something about the system in which they occur. Although we did not directly test water quality, it was clear that the conditions in Gull Rock and Pungo River game lands limited survival of crayfishes because of salinities higher than those found in freshwater. Current reproduction was evident for *F. fodiens* and *P. acutus*. Because we collected only 1 form II male *C. diogenes,* we cannot say whether this species was reproducing. Potential food sources (e.g., allochthonous and autochthonous organic debris) were abundant, and vegetation was present. Crayfishes were rarely seen away from cover. Predation pressure on these crayfishes (especially juveniles) was likely low because the fish community in this system was poor to fair (see *Fish* section of this report). However, plenty of cover-providing habitat was available to crayfishes and likely lessened direct impact by predation. It is unclear whether any of the less widespread species was limited by competition or by abiotic factors other than salinity such as low dissolved oxygen or high acidity.

During our survey, we found 3 of the 8 species historically known to occur in the Tar-Pamlico River Basin. Five species that we did not find, but occur in this river basin, are *Cambarus (Depressicambarus) latimanus* (LeConte, 1856), *C. (D.) reduncus* Hobbs, 1956, *Cambarus (Puncticambarus)* sp. C (a complex related to *C. (P.) acuminatus* Faxon, 1884), *Orconectes (Procericambarus) carolinensis* Cooper and Cooper, 1995, and *Procambarus (O.) medialis* Hobbs, 1975. These species are all known to occur farther upstream in this river basin and are not likely to occur in the vicinity of our survey. This survey has helped to further clarify distribution boundaries of several species in the Tar-Pamlico River Basin.

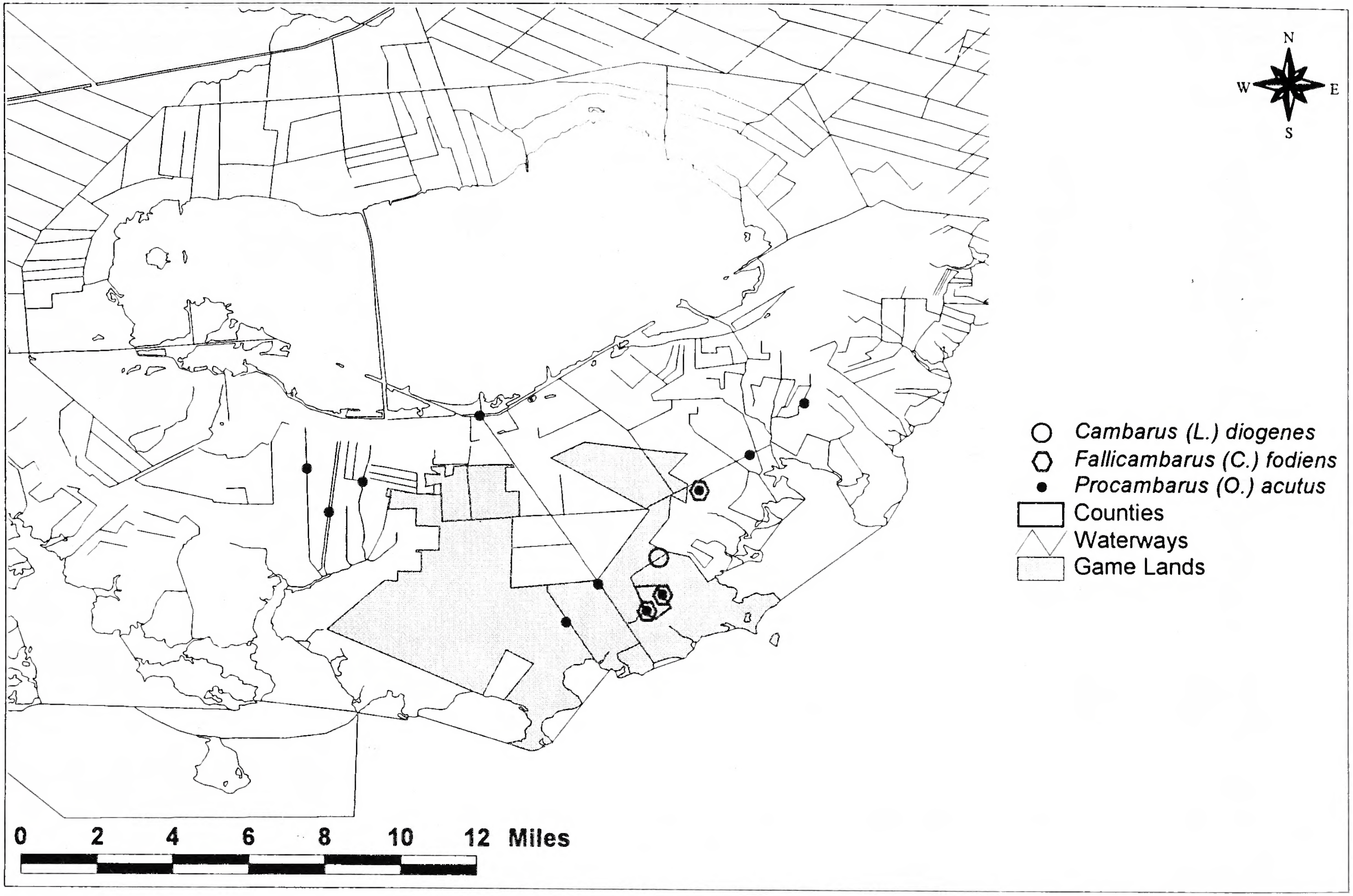

Figure 4a. Map of sites indicating where each species of crayfish was collected in the Gull Rock Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 4a. Crustaceans (crayfishes, crabs, and shrimps) found in Gull Rock Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Cambarus (Lacunicambarus) diogenes							
000606.3btw	6/6/2000	Gull Rock Game Land	Hyde	Canal at bridge	Game Land	rare	A.H. Fullerton
Fallicambarus (Creaserinus) fodiens							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	common	A.H. Fullerton
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	uncommon	A.H. Fullerton
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	uncommon	A.H. Fullerton
Procambarus (Ortmannicus) acutus							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	uncommon	A.H. Fullerton
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	rare	A.H. Fullerton
000606.5btw	6/6/2000	Gull Rock Game Land	Hyde	Roadside swamp	SR 1164	rare	A.H. Fullerton
000607.1btw	6/6/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	rare	A.H. Fullerton
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	common	A.H. Fullerton
000607.7btw	6/7/2000	Gull Rock Game Land	Hyde	Boundary Canal	SR 1117	present	A.H. Fullerton
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	rare	A.H. Fullerton
000608.1btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1110	rare	A.H. Fullerton
000711.3btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay Creek (W)	SR 1121/Bike 2	rare	A.H. Fullerton
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	uncommon	A.H. Fullerton
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	uncommon	A.H. Fullerton
Callinectes sapidus							
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	uncommon	A.H. Fullerton
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	uncommon	A.H. Fullerton
000607.8btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116	rare	A.H. Fullerton
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	common	A.H. Fullerton
000608.3btw	6/8/2000	Gull Rock Game Land	Hyde	Canal (left arm of canal to ocean)	SR 1107	common	A.H. Fullerton
000608.4btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1104	uncommon	A.H. Fullerton
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	uncommon	A.H. Fullerton
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	uncommon	A.H. Fullerton
000711.3btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay Creek (W)	SR 1121/Bike 2	uncommon	A.H. Fullerton
Uca minax							
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	uncommon	A.H. Fullerton
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	common	A.H. Fullerton

Table 4a (cont.). Crustaceans (crayfishes, crabs, and shrimps) found in Gull Rock Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Palaemonetes paludosus							
000606.6btw	6/6/2000	Gull Rock Game Land	Hyde	Lake Mattamuskeet	n/a	present	A.H. Fullerton
000607.3btw	6/7/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	present	A.H. Fullerton
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	present	A.H. Fullerton
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	abundant	A.H. Fullerton
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	present	A.H. Fullerton
000608.1btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1110	uncommon	A.H. Fullerton
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	abundant	A.H. Fullerton
000608.3btw	6/8/2000	Gull Rock Game Land	Hyde	Canal (left arm of canal to ocean)	SR 1107	abundant	A.H. Fullerton
000608.4btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1104	abundant	A.H. Fullerton
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	uncommon	A.H. Fullerton
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	common	A.H. Fullerton
000711.3btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay Creek (W)	SR 1121/Bike 2	present	A.H. Fullerton
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	present	A.H. Fullerton
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	present	A.H. Fullerton

Table 4b. Statistics on carapace lengths (mm) of crayfishes found in Gull Rock Game Land and associated waterways. See text for common names.

	Avg	Std	Min	Max
Cambarus (Lacunicambarus) diogenes				
male II (1 record)	21.5		21.5	21.5
Species Total (1 record)	21.5		21.5	21.5
Fallicambarus (Creaserinus) fodiens				
female (8 records)	16.5	3.1	12.0	20.5
male II (11 records)	16.5	3.3	10.5	21.0
Species Total (19 records)	16.5	3.1	10.5	21.0
Procambarus (Ortmannicus) acutus				
female (1 record)	7.0		7.0	7.0
male I (1 record)	32.5		32.5	32.5
male II (1 record)	10.0		10.0	10.0
Species Total (3 records)	16.5	13.9	7.0	32.5

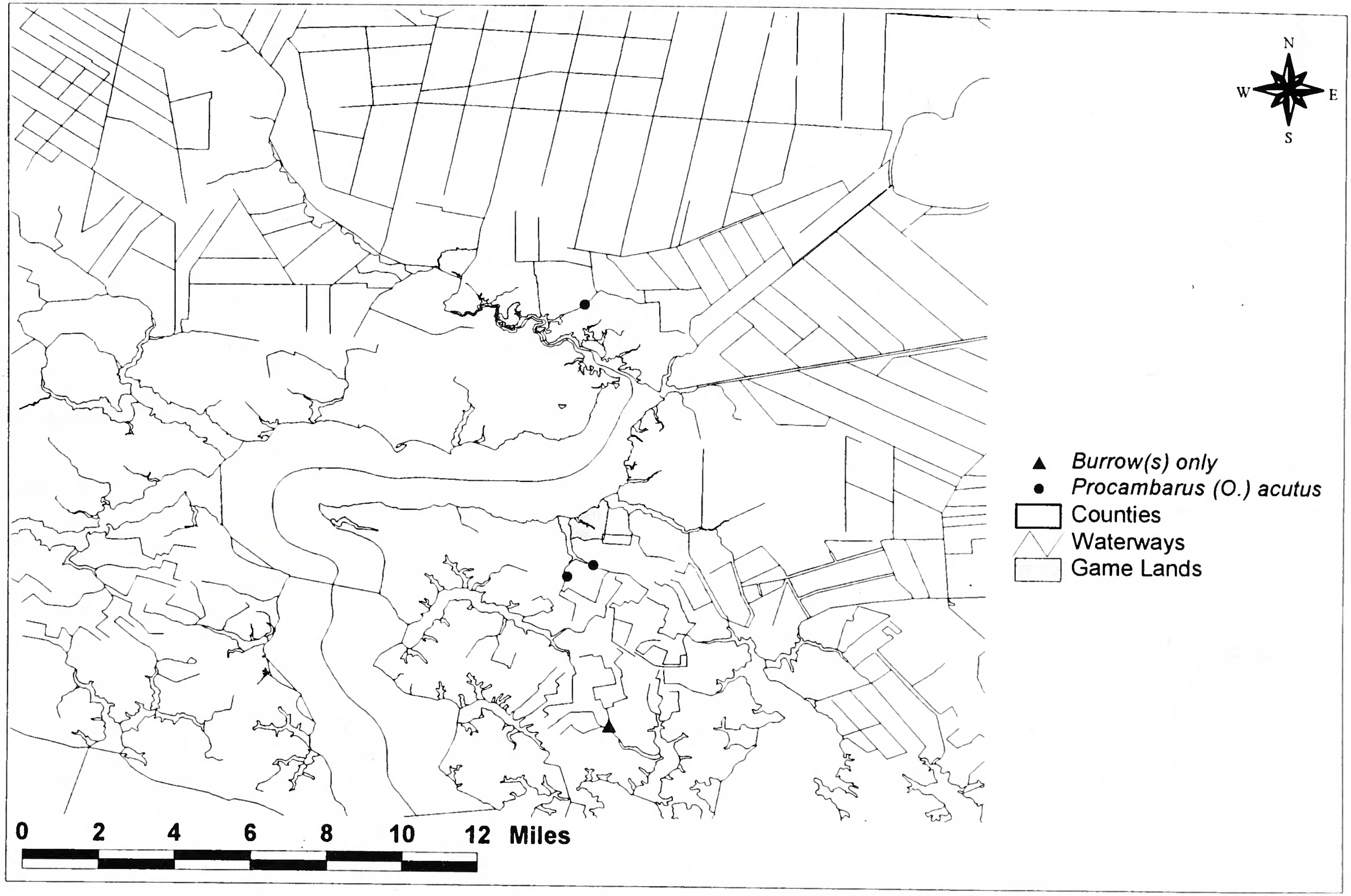

Figure 4b. Map of sites indicating where each species of crayfish was collected in the Pungo River Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 4c. Crustaceans (crayfishes, crabs, and shrimps) found in Pungo River Game Land and associated waterways. See text for common names.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Burrow(s) only							
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	present	A.H. Fullerton
Procambarus (Ortmannicus) acutus							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	rare	A.H. Fullerton
000712.4btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Smith Creek	SR 1143	common	A.H. Fullerton
000713.3btw	7/13/2000	Pungo River Game Land	Hyde	Trib to Pungo River	US 45	rare	A.H. Fullerton
Callinectes sapidus							
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	rare	A.H. Fullerton
Rhithropanopeus harrisii							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	common	A.H. Fullerton
Unidentified crab							
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	rare	A.H. Fullerton
***Penaeus* sp.**							
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	rare	A.H. Fullerton
Palaemonetes paludosus							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	common	A.H. Fullerton
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	patchy common	A.H. Fullerton
000712.6btw	7/12/2000	Pungo River Game Land	Hyde	Canal (trib to?) S of Slade Creek	SR 1145	present	A.H. Fullerton
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	common	A.H. Fullerton
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	common	A.H. Fullerton
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	present	A.H. Fullerton
000713.6btw	7/13/2000	Pungo River Game Land	Beaufort	Lower Dowry Creek	NC 264/Bike 2	rare	A.H. Fullerton

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FRESHWATER FISHES

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Introduction

Fishes are the most numerous and diverse of the major vertebrate groups. Their various morphological, behavioral, reproductive, and physiological adaptations have allowed them to dominate the waters of the world. Fishes can be found in a broad array of habitats, including vernal pools, mountain streams, and the ocean floor. Their dominance is reflected in the number of living species. Over 24,600 species have been described (Moyle and Cech 1996), and it is believed that this number may increase to approximately 28,500 (Nelson 1994). The North American continent harbors approximately 1,100 species of freshwater fish (Burr and Mayden 1992), with 790 (75%) species occurring in the United States (Page and Burr 1991). Nearly 200 native species can be found in North Carolina (Menhinick 1991).

While most of the attention from the public and fisheries biologists is directed towards the game fishes, these species make up only about 5% of the freshwater fish fauna in the United States. The remaining 95% are little known, but charismatic, nongame species, such as darters and minnows. Nongame fishes play a vital role in the balance of aquatic ecosystems. Their diets are diverse, and, in turn, they serve as dietary components for sport fishes, water birds, and other wildlife. They also are important indicators of water quality and can signal when aquatic ecosystems are being negatively impacted. Game fishes also are important components of aquatic ecosystems and provide a source of recreation and employment for many people. Unfortunately, in 1989, the American Fisheries Society regarded 364 North American freshwater fish species as endangered, threatened, or special concern, an increase of 45% in just 10 years (Williams et al. 1989). This number represents approximately one-third of the North American native freshwater fish fauna. Likewise, the southern United States, which supports more native fishes than any comparable size on the North American continent north of Mexico, has experienced a 75% increase in jeopardized fishes since 1989 and a 125% increase in 20 years (Warren et al. 2000). In North Carolina, approximately 25% of the freshwater fishes are state listed. Some of the reasons for this decline include habitat alteration and loss, chemical pollution, overexploitation, and introduction of exotic species. Given this information, it is essential that we better understand the taxonomy, distribution, and conservation needs of the various taxa. Therefore, a fish inventory of the waterways in and around the state-owned Gull Rock Game Land and Pungo River Game Land was initiated to ascertain some of this needed information.

Methods

The freshwater fish survey of Gull Rock Game Land and Pungo River Game Land was conducted during the spring and summer of 2000. Refer to the Report Introduction for details on history of land use, drainage basin and waterway descriptions, and a map of all the sites that were surveyed. Waterways typically were accessed at bridge crossings or roadside access points.

Since most waterways were canals, ditches, or swamps, we surveyed as many habitat types as possible near the access points. For waterways that were more stream-like, we sampled upstream for an arbitrary distance (usually 30 minutes of walking) until we felt that we had covered most habitat types present. Typical distances were 100 - 400 meters.

Freshwater fishes were collected using a variety of techniques depending on the conditions of the site being surveyed (e.g., water depth, visibility, substrata types). The most common method used was dip netting. This method was predominantly used because most of the waterways we encountered had high conductivities making them difficult to electrofish. We typically use electrofishing as our primary survey technique due to its advantages regarding efficiency and effectiveness, but only 5 sites between the 2 game lands were sampled in this manner. Given the conditions of the waterways we encountered, the use of minnow traps also was implemented to help augment the accuracy of our surveys. Most fishes collected were identified to species and released unharmed. However, it was necessary to perform some of the identifications in the laboratory. These identifications were carried out by fixing the fish in 10% formalin and preserving them in 70% ethanol. Once the fishes were preserved, they were identified with the use of a compound microscope (Nikon). Fishes were identified according to Menhinick (1991), Page and Burr (1991), Rhode et al. (1994), and Jenkins and Burkhead (1994). Dr. Wayne C. Starnes and others (G.M. Hogue, T.L. Fullbright, and Dr. M.E. Raley) from the NC State Museum of Natural Sciences verified some of the identifications. Besides presence-absence data, relative abundance and recent reproduction information were noted for each species to determine population health.

For fishes, a survey effectiveness score (SES) was determined at each site and the overall average was calculated. The SES ranged from 1 to 5, with 1 being the lowest and 5 the highest. The score is arbitrary and is based on the perceived sampling effectiveness at each site based on factors such as water depth and clarity, area covered, techniques utilized, etc. The purpose of the score is to give a sense of accuracy to the reported species for a given area.

Results

Gull Rock Game Land

Over 5 days from 6 June to 12 July 2000, 27 sites were inventoried and fish were collected or observed at 25 sites (Figure 5a). Twenty-five species representing 18 families were documented during the survey of Gull Rock Game Land (Tables 5a and 5b). Of the 55 species of freshwater fish species that have been documented in the Hyde County portion of the Tar-Pamlico River Basin (Menhinick 1991), we confirmed the presence of only 21 of these species. A single species solely listed as a marine species that may enter freshwater (Menhinick 1991) also was collected. Limitations as to our sampling techniques, and access of all available habitats and sampling range within the county were the most likely reasons for the absence of particular species. We did document the presence of 3 species that were not previously documented from the Hyde County portion of the Tar-Pamlico River Basin: *Erimyzon oblongus* (creek chubsucker), *Acantharchus pomotis* (mud sunfish), and *Fundulus confluentus* (marsh killifish). Overall, abundance, distribution, and recent reproduction were difficult to determine for most fish species given that our SES was 1.98.

Pungo River Game Land

Over 2 days from 12 July to 13 July, 14 sites were inventoried and fishes were collected or observed at all 14 localities (Figure 5b). Seventeen species representing 14 families were documented during the survey of Pungo River Game Land (Tables 5c and 5d). Of the approximately 55 species that have been documented in the Hyde County portion of the Tar-Pamlico River Basin (Menhinick 1991), we confirmed the presence of only 15 of these species. A single species solely listed as a marine species that may enter freshwater (Menhinick 1991) also was collected. Limitations as to our sampling techniques, and access of all available habitats and sampling range within the county were the most likely reasons for the absence of particular species. We did document the presence of 1 species that was not previously documented from the Hyde County portion of the Tar-Pamlico River Basin: *Erimyzon oblongus* (creek chubsucker). Overall, abundance, distribution, and recent reproduction were difficult to determine for most fish species given that our SES was 1.71.

Discussion

The waterways associated with Gull Rock Game Land and Pungo River Game Land contain a relatively low diversity and distribution of fish species given past records and distributions (Menhinick 1991). Overall, 27 species representing 19 families were collected between the 2 game lands. With the exception of *Gambusia holbrookii*, most of the species tended to occur over a restricted area. Species abundance was typically low at many sites with the killifishes and livebearers usually comprising a majority of the biomass. The low distribution and abundance of a number of the species were likely significantly affected by the lack of intensive survey techniques. A number of sites had characteristics that made them virtually impossible to backpack electrofish, while even some of the sites we electrofished were difficult due to the water clarity. Therefore, dip netting became the primary, but less than desired, technique during the survey, resulting in a SES below 2 for both game lands. Overall, the area we surveyed was mostly rural, resulting in minimal urbanization effects and some agricultural impacts, which may tend to reflect different results than those reported here. Unfortunately, we do not have any recent survey results for comparison to obtain an accurate reflection of the species composition and distribution of the area.

While no threatened or endangered fish species was collected during the survey of Gull Rock Game Land or Pungo River Game Land, continual research and status surveys are needed to determine the present status of each species. Three species were collected during the survey that were previously undocumented from the Hyde County portion of the Tar-Pamlico River Basin (Menhinick 1991), which is most likely due to a lack of surveys in the area. Current land management practices, including agriculture and urbanization, are having an effect on the fish fauna in North Carolina. As nongame biologists, we need to identify which species are at risk and identify ways to reduce or eliminate the impacts.

Figure 5a. Map of sites indicating where fishes were collected in the Gull Rock Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 5a. Fish species found in Gull Rock Game Land and associated waterways.

Anguillidae	
Anguilla rostrata	american eel
Aphredoderidae	
Aphredoderus sayanus	pirate perch
Atherinidae	
Menidia beryllina	inland silverside
Belonidae	
Strongylura marina	Atlantic needlefish
Bothidae	
Paralichthys lethostigma	southern flounder
Catostomidae	
Erimyzon oblongus	creek chubsucker
Centrarchidae	
Acantharchus pomotis	mud sunfish
Chaenobryttus gulosus	warmouth
Enneacanthus gloriosus	bluespotted sunfish
Lepomis gibbosus	pumpkinseed
Lepomis macrochirus	bluegill
Micropterus salmoides	largemouth bass
Cyprinidae	
Notemigonus crysoleucas	golden shiner
Cyprinodontidae	
Fundulus confluentus	marsh killifish
Fundulus heteroclitus	mummichog
Lucania parva	rainwater killifish
Esocidae	
Esox americanus	redfin pickerel
Ictaluridae	
Ameiurus nebulosus	brown bullhead
Lepisosteidae	
Lepisosteus osseus	longnose gar
Mugillidae	
Mugil cephalus	striped mullet

Table 5a (cont.). Fish species found in Gull Rock Game Land and associated waterways.

Percichthyidae	
Morone americana	white perch
Percidae	
Etheostoma fusiforme	swamp darter
Poeciliidae	
Gambusia holbrookii	eastern mosquitofish
Sciaenidae	
Leiostomus xanthurus	spot
Umbridae	
Umbra pygmaea	eastern mudminnow

Table 5b. Fish species found in Gull Rock Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Acantharchus pomotis							
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	rare	B.T. Watson
Ameiurus nebulosus							
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	rare	B.T. Watson, W.C. Starnes
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson, W.C. Starnes
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	rare	B.T. Watson, W.C. Starnes
000711.2btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay	SR 1124/Bike 2	rare	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	rare	B.T. Watson
Anguilla rostrata							
000607.1btw	6/6/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	rare	B.T. Watson
000607.3btw	6/7/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	rare	B.T. Watson
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	rare	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	rare	B.T. Watson
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	common	B.T. Watson
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	rare	B.T. Watson
Aphredoderus sayanus							
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	common	B.T. Watson
000607.7btw	6/7/2000	Gull Rock Game Land	Hyde	Boundary Canal	SR 1117	uncommon	B.T. Watson
Chaenobryttus gulosus							
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	common	B.T. Watson, W.C. Starnes

Table 5b (cont.). Fish species found in Gull Rock Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Enneacanthus gloriosus							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	patchy common	B.T. Watson
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	uncommon	B.T. Watson
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	uncommon	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	common	B.T. Watson, W.C. Starnes
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	rare	B.T. Watson
000711.2btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay	SR 1124/Bike 2	common	B.T. Watson
000711.3btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay Creek (W)	SR 1121/Bike 2	common	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	common	B.T. Watson
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	common	B.T. Watson
Erimyzon oblongus							
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	uncommon	B.T. Watson
Erimyzon sp.							
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	uncommon	W.C. Starnes
Esox americanus							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	rare	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	rare	B.T. Watson
Etheostoma fusiforme							
000711.2btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay	SR 1124/Bike 2	rare	B.T. Watson
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	rare	B.T. Watson
Fundulus confluentus							
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	rare	B.T. Watson, W.C. Starnes

Table 5b (cont.). Fish species found in Gull Rock Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Fundulus heteroclitus							
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	uncommon	B.T. Watson
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	common	B.T. Watson, W.C. Starnes
Gambusia holbrookii							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	patchy common	B.T. Watson
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	present	B.T. Watson
000606.5btw	6/6/2000	Gull Rock Game Land	Hyde	Roadside swamp	SR 1164	common	B.T. Watson
000606.6btw	6/6/2000	Gull Rock Game Land	Hyde	Lake Mattamuskeet	n/a	present	B.T. Watson
000607.1btw	6/6/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	present	B.T. Watson
000607.3btw	6/7/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	present	B.T. Watson
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	common	B.T. Watson
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	common	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	common	B.T. Watson
000607.7btw	6/7/2000	Gull Rock Game Land	Hyde	Boundary Canal	SR 1117	rare	B.T. Watson
000607.8btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116	present	B.T. Watson
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	common	B.T. Watson
000608.1btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1110	abundant	B.T. Watson
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	uncommon	B.T. Watson
000608.3btw	6/8/2000	Gull Rock Game Land	Hyde	Canal (left arm of canal to ocean)	SR 1107	present	B.T. Watson
000608.4btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1104	abundant	B.T. Watson
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	common	B.T. Watson
000608.6btw	6/8/2000	Gull Rock Game Land	Hyde	Swamp near Rose Canal	US 264	present	B.T. Watson
000711.2btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay	SR 1124/Bike 2	common	B.T. Watson
000711.3btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay Creek (W)	SR 1121/Bike 2	common	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	common	B.T. Watson
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	common	B.T. Watson
Leiostomus xanthurus							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	rare	B.T. Watson, W.C. Starnes
000608.4btw	6/8/2000	Gull Rock Game Land	Hyde	Roadside ditch	SR 1104	rare	B.T. Watson

Table 5b (cont.). Fish species found in Gull Rock Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Lepisosteus osseus							
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	rare	B.T. Watson
000608.5btw	6/8/2000	Gull Rock Game Land	Hyde	Waupoppin Canal	SR 1311	uncommon	B.T. Watson
Lepomis gibbosus							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	rare	B.T. Watson
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	rare	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	rare	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	rare	B.T. Watson
Lepomis macrochirus							
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	common	B.T. Watson
000712.1btw	7/12/2000	Gull Rock Game Land	Hyde	Quarter Canal	SR 1124 @ SR 1125	uncommon	B.T. Watson
Lucania parva							
000606.1btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (front)	SR 1164	present	B.T. Watson, W.C. Starnes
000606.2btw	6/6/2000	Gull Rock Game Land	Hyde	Waterfowl Impoundment (back)	SR 1164	present	B.T. Watson
000607.5btw	6/7/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1118	rare	B.T. Watson
000607.9btw	6/7/2000	Gull Rock Game Land	Hyde	Wetland @ Outfall Canal	SR 1330	uncommon	B.T. Watson, W.C. Starnes
000711.1btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Swanquarter Bay	NC 45/Bike 2	uncommon	B.T. Watson, W.C. Starnes
Menidia beryllina							
000607.8btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116	present	B.T. Watson, W.C. Starnes
Micropterus salmoides							
000711.2btw	7/11/2000	Gull Rock Game Land	Hyde	Canal to Juniper Bay	SR 1124/Bike 2	rare	B.T. Watson
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	rare	B.T. Watson
Morone americana							
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	present	W.C. Starnes

Table 5b (cont.). Fish species found in Gull Rock Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Mugil cephalus							
000606.6btw	6/6/2000	Gull Rock Game Land	Hyde	Lake Mattamuskeet	n/a	present	B.T. Watson
000607.4btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116 @ US 264	uncommon	B.T. Watson, W.C. Starnes
000607.8btw	6/7/2000	Gull Rock Game Land	Hyde	Lake Landing Canal	SR 1116	present	B.T. Watson
Notemigonus crysoleucas							
000711.4btw	7/11/2000	Gull Rock Game Land	Hyde	Juniper Canal	SR 1121 @ SR 1122	rare	B.T. Watson
Paralichthys lethostigma							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	rare	W.C. Starnes
Strongylura marina							
000608.2btw	6/8/2000	Gull Rock Game Land	Hyde	Canal to ocean	SR 1108 @ SR 1111	rare	B.T. Watson
Umbra pygmaea							
000606.4btw	6/6/2000	Gull Rock Game Land	Hyde	Canal	SR 1164	rare	B.T. Watson
000607.3btw	6/7/2000	Gull Rock Game Land	Hyde	Outfall Canal	SR 1164	rare	B.T. Watson
000607.6btw	6/7/2000	Gull Rock Game Land	Hyde	Ditch connected to Boundary Canal	SR 1117	common	B.T. Watson
000608.6btw	6/8/2000	Gull Rock Game Land	Hyde	Swamp near Rose Canal	US 264	abundant	B.T. Watson
000712.2btw	7/12/2000	Gull Rock Game Land	Hyde	Roadside canal	US 264/NC 45/Bike 2	rare	B.T. Watson

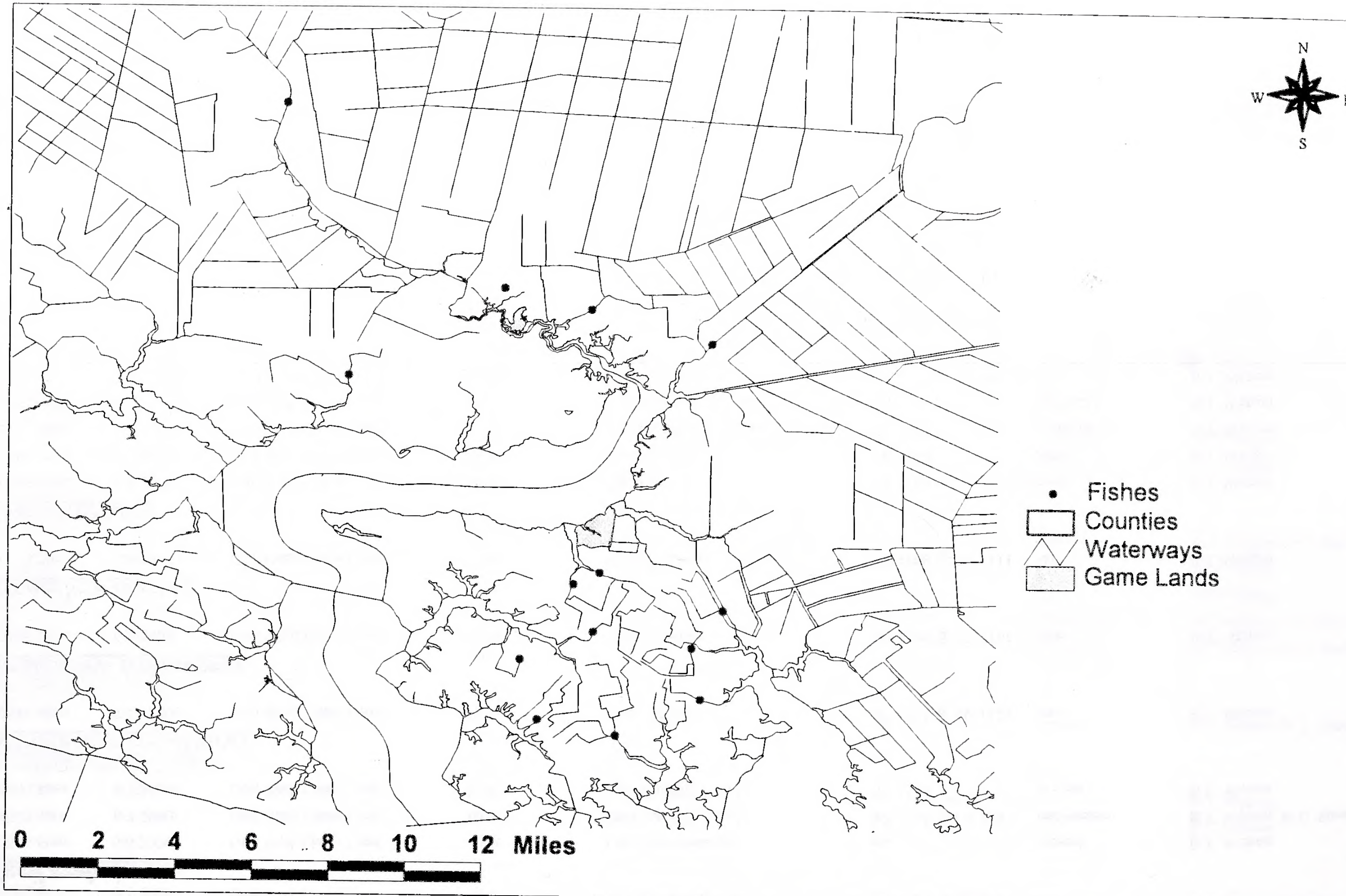

Figure 5b. Map of sites indicating where fishes were collected in the Pungo River Game Land aquatic inventory, Hyde County, North Carolina, 2000.

Table 5c. Fish species found in Pungo River Game Land and associated waterways.

Anguillidae	
Anguilla rostrata	american eel
Aphredoderidae	
Aphredoderus sayanus	pirate perch
Atherinidae	
Menidia beryllina	inland silverside
Catostomidae	
Erimyzon oblongus	creek chubsucker
Centrarchidae	
Enneacanthus gloriosus	bluespotted sunfish
Lepomis macrochirus	bluegill
Cyprinidae	
Notemigonus crysoleucas	golden shiner
Cyprinodontidae	
Cyprinodon variegatus	sheepshead minnow
Fundulus heteroclitus	mummichog
Lucania parva	rainwater killifish
Engraulidae	
Anchoa mitchilli	bay anchovy
Ictaluridae	
Ameiurus nebulosus	brown bullhead
Mugillidae	
Mugil cephalus	striped mullet
Percidae	
Etheostoma fusiforme	swamp darter
Poeciliidae	
Gambusia holbrookii	eastern mosquitofish
Sciaenidae	
Leiostomus xanthurus	spot
Umbridae	
Umbra pygmaea	eastern mudminnow

Table 5d. Fish species found in Pungo River Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Ameiurus nebulosus							
000713.1btw	7/13/2000	Pungo River Game Land	Hyde	Canal to Rose Bay	US 264 0.4 mi NW SR 1139	rare	B.T. Watson, W.C. Starnes
Anchoa mitchilli							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	rare	B.T. Watson, W.C. Starnes
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	common	B.T. Watson
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	rare	B.T. Watson
Anguilla rostrata							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	rare	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	rare	B.T. Watson
Aphredoderus sayanus							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	rare	B.T. Watson
000713.3btw	7/13/2000	Pungo River Game Land	Hyde	Trib to Pungo River	US 45	uncommon	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	rare	B.T. Watson
Clupeidae							
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	present	B.T. Watson
Cyprinodon variegatus							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	uncommon	B.T. Watson
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	rare	B.T. Watson, W.C. Starnes
Enneacanthus gloriosus							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	common	B.T. Watson
Erimyzon oblongus							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	rare	B.T. Watson

Table 5d (cont.). Fish species found in Pungo River Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Etheostoma fusiforme							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	common	B.T. Watson
000713.3btw	7/13/2000	Pungo River Game Land	Hyde	Trib to Pungo River	US 45	common	B.T. Watson
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	rare	B.T. Watson
Fundulus heteroclitus							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	rare	B.T. Watson
000712.5btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Slade Creek (NE)	SR 1142	present	B.T. Watson
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	uncommon	B.T. Watson, W.C. Starnes
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	rare	B.T. Watson
Gambusia holbrookii							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	common	B.T. Watson
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	uncommon	B.T. Watson
000712.4btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Smith Creek	SR 1143	common	B.T. Watson
000712.5btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Slade Creek (NE)	SR 1142	common	B.T. Watson
000712.6btw	7/12/2000	Pungo River Game Land	Hyde	Canal (trib to?) S of Slade Creek	SR 1145	common	B.T. Watson
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	common	B.T. Watson
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	common	B.T. Watson
000712.9btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (N)	SR 1139	common	B.T. Watson
000713.1btw	7/13/2000	Pungo River Game Land	Hyde	Canal to Rose Bay	US 264 0.4 mi NW SR 1139	common	B.T. Watson
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	uncommon	B.T. Watson
000713.3btw	7/13/2000	Pungo River Game Land	Hyde	Trib to Pungo River	US 45	uncommon	B.T. Watson
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	common	B.T. Watson
000713.5btw	7/13/2000	Pungo River Game Land	Beaufort/Hyde	Pungo River and side canal	NC 45	common	B.T. Watson
000713.6btw	7/13/2000	Pungo River Game Land	Beaufort	Lower Dowry Creek	NC 264/Bike 2	uncommon	B.T. Watson
Leiostomus xanthurus							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	rare	B.T. Watson
000712.4btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Smith Creek	SR 1143	rare	B.T. Watson, W.C. Starnes

Table 5d (cont.). Fish species found in Pungo River Game Land and associated waterways.

Site No.	Date	Project	County	Waterway	Road No.	Abundance	Identified By
Lepomis macrochirus							
000713.1btw	7/13/2000	Pungo River Game Land	Hyde	Canal to Rose Bay	US 264 0.4 mi NW SR 1139	rare	B.T. Watson
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	uncommon	B.T. Watson
Lucania parva							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	common	B.T. Watson
000712.3btw	7/12/2000	Pungo River Game Land	Hyde	Smith Creek	SR 1143-	rare	B.T. Watson, W.C. Starnes
000712.4btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Smith Creek	SR 1143	rare	B.T. Watson
000712.7btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Germantown Bay	SR 1141A	common	B.T. Watson, W.C. Starnes
000712.8btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Rose Bay (S)	SR 1141A	rare	B.T. Watson
000713.6btw	7/13/2000	Pungo River Game Land	Beaufort	Lower Dowry Creek	NC 264/Bike 2	rare	B.T. Watson
Menidia beryllina							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	rare	B.T. Watson, W.C. Starnes
Mugil cephalus							
000712.10btw	7/12/2000	Pungo River Game Land	Hyde	Canal to Fortescue Creek	SR 1145	rare	B.T. Watson, W.C. Starnes
Notemigonus crysoleucas							
000713.2btw	7/13/2000	Pungo River Game Land	Hyde	Old State Canal	SR 1303 @ SR 1302	common	B.T. Watson, W.C. Starnes
Umbra pygmaea							
000712.4btw	7/12/2000	Pungo River Game Land	Hyde	Trib to Smith Creek	SR 1143	rare	B.T. Watson
000713.4btw	7/13/2000	Pungo River Game Land	Hyde	Swamp near Pungo River	NC 45	common	B.T. Watson

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